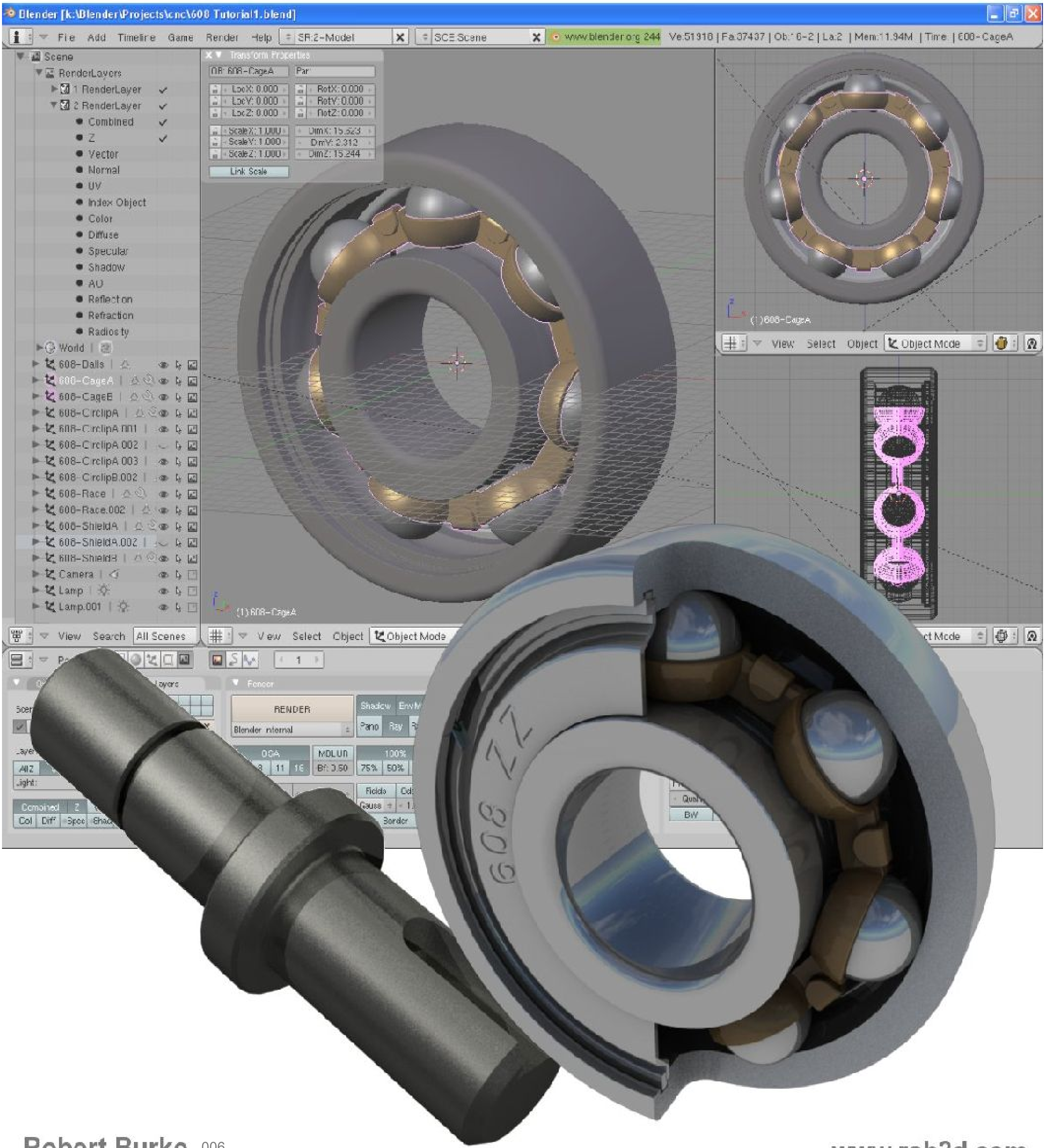
PRECISION MODELLING

A Guide to modelling parts and components accurately using Blender



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Introduction

This guide was created to assist Artists and Engineers, to learn the basics of mesh modelling of non deformable objects with 'Blender'. It uses a structured approach to introducing Blenders tools and work-methods. Following the guide should enable you to become familiar with blender and create models from the simplest of parts to complex accurate engineering assemblies and designs.

The guide focuses solely on Blenders Mesh Modelling capabilities, it ignores the myriad of animation, texturing and photo-realistic rendering tools and concentrates solely on getting started and producing accurate models suited for both artistic and engineering purposes.

The guide was originally made as a series of web pages that documented the design ideas and Blender methods used do design a few of the components I will be making for a rebuild of my CNC router. It has been ported to this .pdf book from the web pages, so some references in the guide will still only relate to the on-line version.

The Small Print

Contents

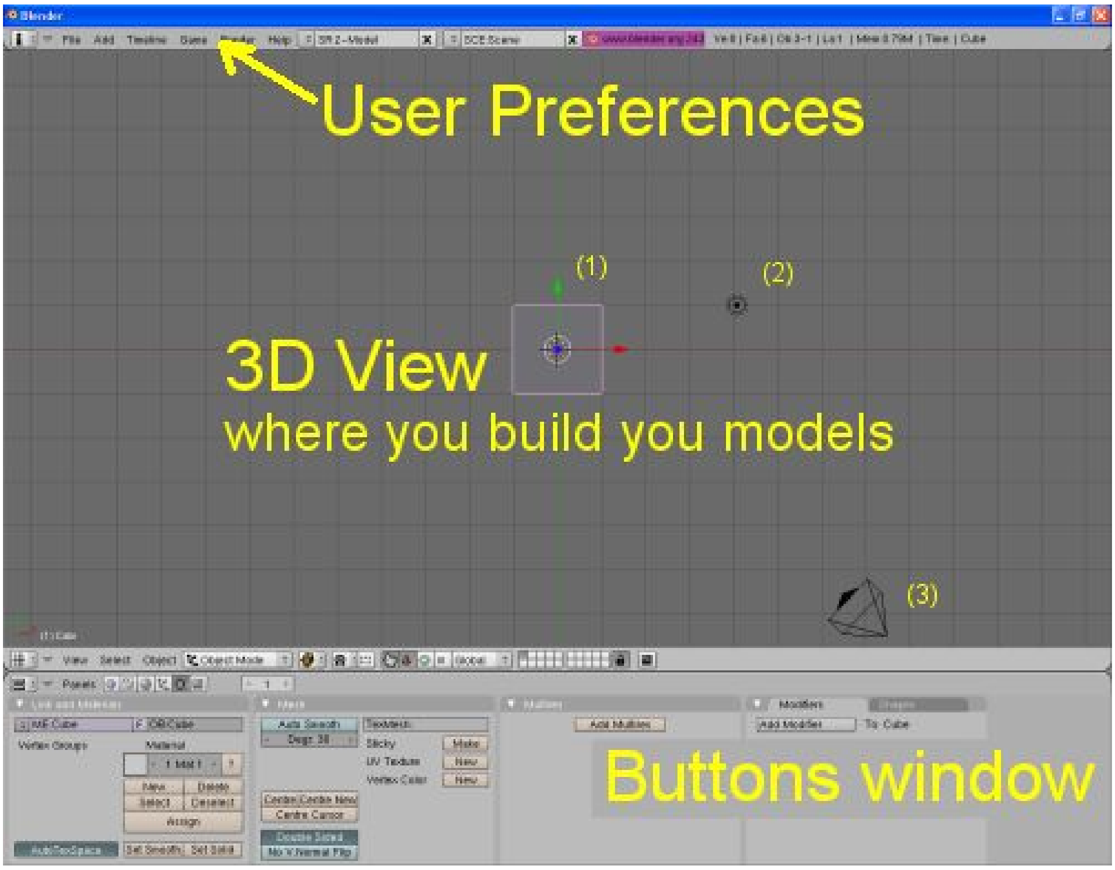
Starting Blender

There is a wealth of information available on the Internet in the form of manuals, guides and tutorials that cover the full potential of this program. This Guide is intended as a starter for people interested in the creation of mesh models and more specifically, dimensionally accurate mesh models. Appendix 1 gives a short list of useful Internet links.

Obtaining and loading Blender

The Open Source and freely available creative package Blender can be downloaded from www.blender.org. Once on the site, click the download link to open the download page. Choose the file to suit your operating system and follow the simple installation instructions at the bottom of the download page to install the program.

What you see when the program starts



When you run blender for the first time you are presented with the default screen. It contains the user preference's window at the top of the screen. The main 3D work area in the centre of the screen and the buttons window at the bottom of the screen.

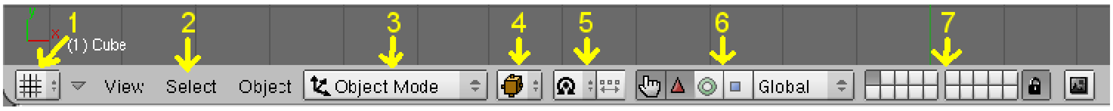
A Quick Overview of the controlls.

Relevant sections of the program

When you first start modelling, the main two screens are already open, the 3D workspace and the Buttons window. A cube object (1) is in the centre of the 3D view and the window is orientated so you are looking down onto the top of the cube. There is also a Lamp (2) to illuminate the cube and a Camera (3) to output a 2D bitmap of the cube.

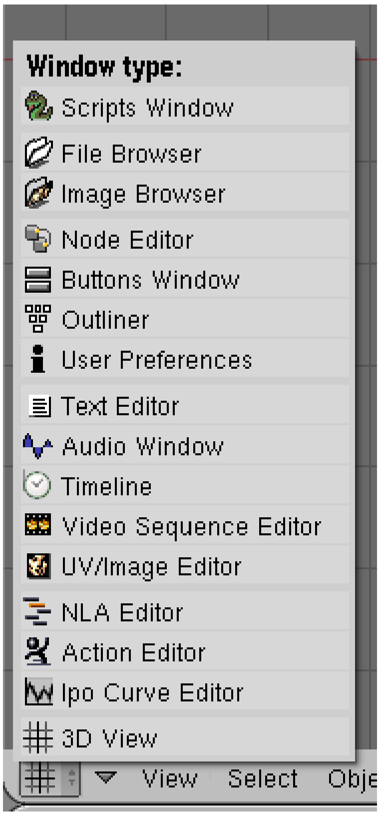
3D View: Header Bar

At the bottom of the 3D view is blenders View Header Bar. The purpose of each section within the view header is detailed below.



1) Window Type

Click on the window type button and a menu will appear showing all the different window types. Each window has a function within the process of 3D modelling, image creation or animation. However our initial interest lies just with the following windows:



3D View:

Buttons Window:
This contains Blenders control buttons.

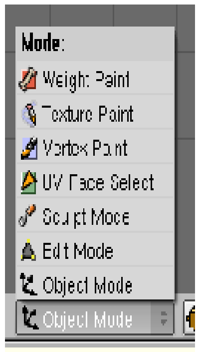
Outliner:
A structured view of objects within the 3D scene and there relationships to each other.

Script Window:
To run useful add on scripts.

2) Pull up menu
A context sensitive menu showing the operations that can be carried out and the keyboard shortcut for the operation.

3) Mode:

The operating mode for the window, initially we will only be using Object mode and Edit mode.
Object mode is where assemblies of components are constructed.
Edit mode is where the individual components are modelled.

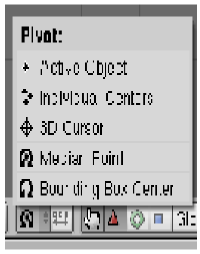


4) Draw type

This is the way the model is displayed on screen. The two useful types we are interested in for modelling are Wireframe and Solid.

5) Pivot Point

This gives a choice of centre points for rotating and scaling the 3D models.

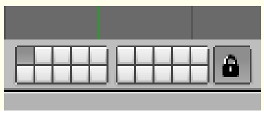


6) Widget control

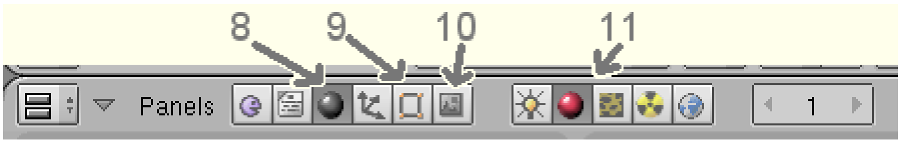
Click the hand icon to de-select this. It should show a light grey background

7) Layers

These allow you to organise components in big assemblies, only showing those that are needed.



Buttons Window Header Bar



Context Buttons:
These change the control button options in context with the operation you are performing.

8) Material Context Button
Brings up a choice of material texturing and lighting options.

9) Editing Button
Brings up the modelling tools.

10) Render Button
Controls the output to a 2D-bitmap image.

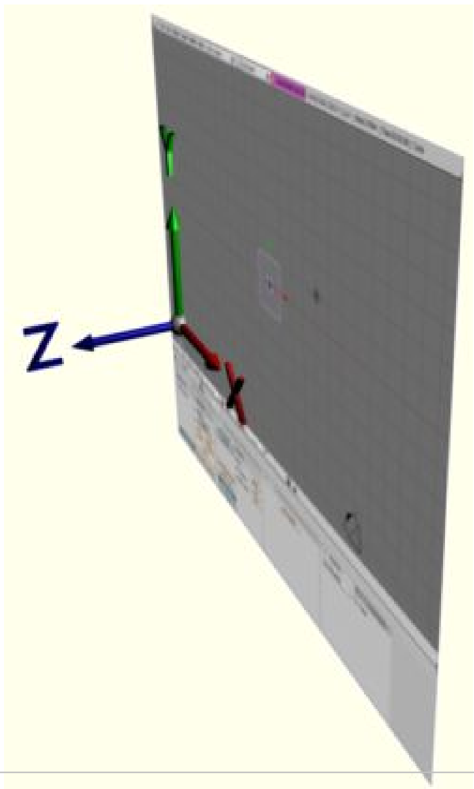
11) Material Sub-context
Each context button has sub context options.

Understanding 3D co-ordinates and Blenders 3D views

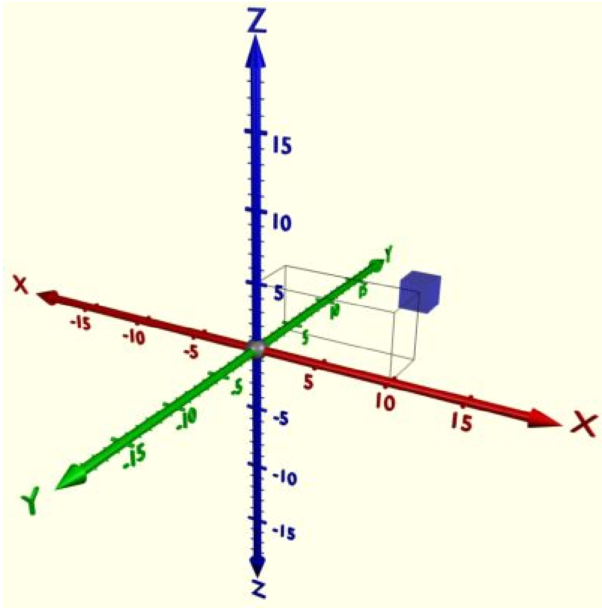
When you first run blender you are presented with a view of the workspace looking directly down from above. The screen in this position represents the X and Y-axis. The Z-axis is coming away from the screen directly towards you.

You can change the view direction by either clicking and holding the middle mouse button whilst dragging the mouse to rotate the view around a point in 3D space, or using one of the pre-set views accessed via the number buttons on the right of the keyboard. (Num Pad Buttons)

When modelling in blender you draw parallel to the surface of the view at the depth of the 3D Cursor (small cross hair positioned by clicking the Left Mouse Button), so the view rotation and position of the cursor is important to the desired outcome.



Blender uses the right hand co-ordinate system with the Z-axis pointing upwards. This is in common with the co-ordinate systems used by most common 3D CAD packages. Its worth noting though, that some programs use a co-ordinate system where the Y axis points up and it may be necessary to rotate the model if exporting your model into a program with this configuration.



Cartesian Co-ordinates

Blender displays the co-ordinate as:
DX 0.0000 DY 0.0000 DZ 0.0000 (0.0000)
When moving or extruding a vertex the bracketed figure denotes the distance from the start point and DX, DY, DZ will change relative to the distance along the axis relative to the start point.

In object mode The Transform Properties pane, accessed by pressing the N key, displays the objects position, relative to the global co-ordinates. It also gives details of its rotation, scale and bounding box size. The object centre co-ordinates of the blue cube in the Cartesian co-ordinates diagram are displayed in the Transform properties window.

Blender units and precision

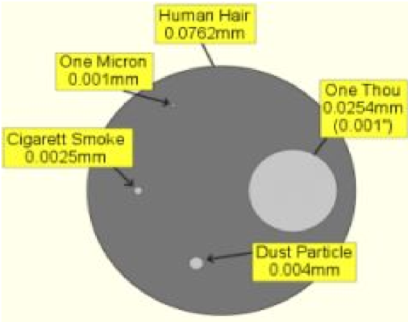
In order to make blender units represent a real world unit it is necessary to assign a dimension size to the blender unit. When Blender first opens you are presented with the default cube measuring 2 blender units wide by 2 blender units deep by 2 blender units high. When importing a VRML or STL file into a rapid prototyping machine it is necessary to tell the software what dimension the units represent. So in order to manufacture an accurate 3D model in Blender and export it to a 3D printer or CNC machine, you need to know what the blender unit represents as a real world measurement.

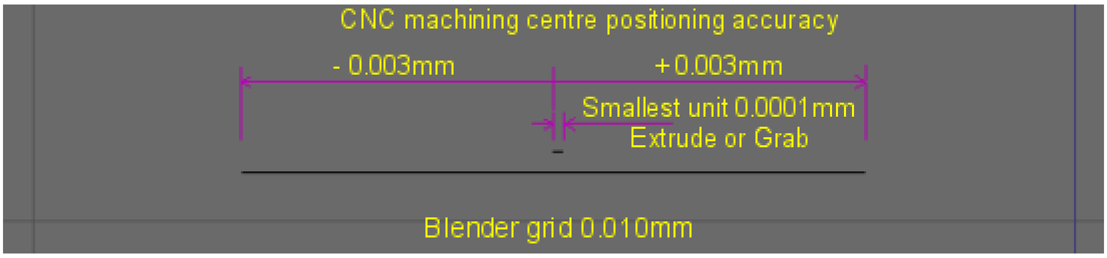
The 3D world within Blender isn’t an unlimited space and there are restrictions as to how big a model can be. Size is limited by the available power and fall-off distance of the lights, the maximum clipping distance of the view camera and the maximum clipping distance of the render (output) camera. Complexity of a model is limited by the amount of vertices your system can handle. The more powerful a machine you have the more vertices you will be able to handle before the computer starts to lag behind the speed you can model at.

So how big should I make a blender unit?
If you were considering modelling a precision component or assembly, being able to model down to sub micron accuracy would be a distinct advantage. So if we consider one blender unit to equal one millimetre how accurate can we get? Blender allows you to numerically input the distance of vertices to the precision of 4 decimal places (0.0000). Say you extrude a vertex 0.0001mm along the X-axis you have set its position 1/10th of a micron from the original. Pretty darn accurate and given that the best CNC machining centres can position to an accuracy of plus or minus 3 microns, you can model to a much greater accuracy than you could ever manufacture to. The draw back to this is your viewable workspace will be limited to a cube with 10 metre sides. This is due to the clipping limit of the view camera, but unless you are designing a gantry mill to cut the wing spars for an Air-Bus A380 this shouldn't present a problem.

Putting Size into Perspective

- The human hair is around 76 microns thick.
- Most general purpose machine tools in skilled hands would be able to work within two thousands of an inch (50 microns)
- The best CNC machining centres can position to an accuracy of plus or minus 3 micron, with repeatability of plus or minus 1 micron.
- A 100mm-iron bar will expand 0.012mm with a rise in temperature of 10 degrees C





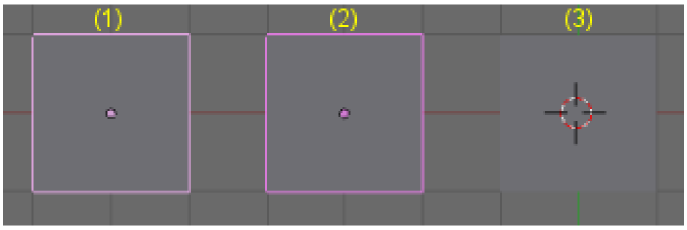
Other scales could be chosen for precision work such as 1 blender unit = 10mm giving a work area of 100 cubic metres, however this confuses the process and you constantly need to be aware of where the decimal point goes when you are entering extrude lengths etc.

For architectural designs it is common to use a scale of 1 blender unit = 1 metre allowing a viewable design space of 10 cubic kilometres and an accuracy of 0.1mm

When blender first opens the view has a cube object in the centre. This is one of several primitive shapes available to you that can be altered to form your component. In Object Mode the shape appears as a solid cube and you are limited to being able to move its position within the global space, rotate it about a chosen point or scale the whole model. By pressing the Tab key you enter Edit Mode and the corners of the cube now have a yellow dot on them, connected by yellow edges. The yellow denotes the vertices are selected. In edit mode you can move the position of any selected vertices, add, join or delete vertices, fill the area between any three or four vertices with a face and much more to construct your model.

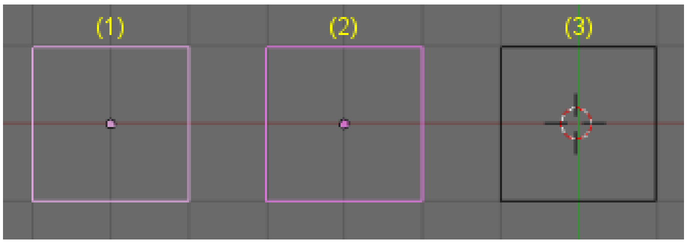
Object Mode - Solid View

Cube (1) is selected with focus. If you press Tab this cube will become available to edit in edit mode.
Cube (2) is selected.
Cube (3) is not selected



Object Mode - Wire View

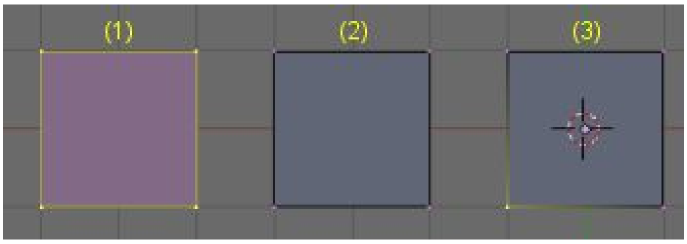
Cube (1) is selected with focus.
Cube (2) Is selected.
Cube (3) is not selected.



Edit Mode - Solid View

Cube (1) All vertices selected.

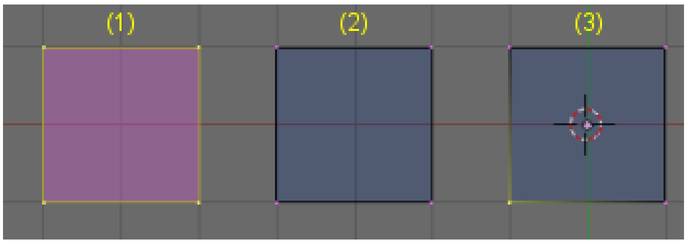
Cube (2) No vertices selected.
Cube (3) One vertex selected. Note the edges fade from yellow selected end to black deselected end.



Edit Mode - Wire View

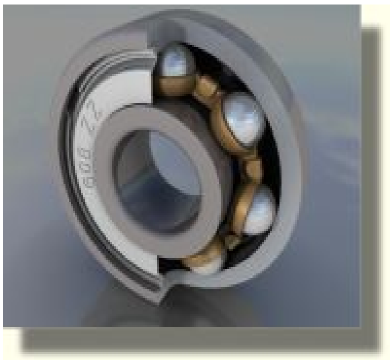
Cube (1) All vertices selected.

Cube (2) No vertices selected.
Cube (3) One vertex selected



Blender has a wealth of tools that allow you to model almost anything and these will be described in the following tutorials. If you are new to 3D, work through the tutorials in sequence; drawing methods and the use of tools are introduced and described as the tutorials progress getting less detailed as your experience progresses. If you get stuck, simply go back through the tutorials to where the tool or method you are struggling with was introduced. The initial description of the process will be the most detailed and helpful.

Modelling a 608 Bearing

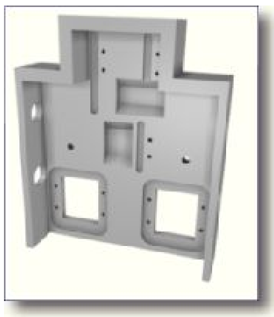


With the experience of modelling the Bearing its time to put the Bearings to use. The next tutorial constructs a V-roller and Axle that will be used to run on the Guides of my CNC machine.

Building A V-Roller Guide Assembly

If you have completed in sequence all the tutorials above you should now be comfortable with Blenders way of modelling. This next part looks at positioning the V-roller's alongside other components and designing a casting around them. The casting will form the X-axis of my CNC router.

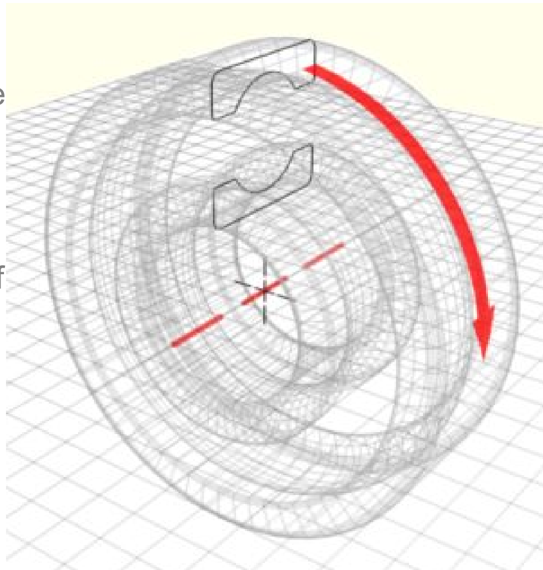
Design Steps for a Casting



Modelling a 608 Bearing Part-1 Reference Geometry

To introduce you to Blenders modelling tools I will walk through the process of designing a 608 Bearing, the type used in skateboards and in-line skates. The geometry from the bearings will later be used in the design of the other components and castings.

I will use this tutorial to introduce some of the basic modelling techniques that can be used to build components accurately. Two bearings will be covered in the tutorial, a detailed model with a large number of vertices and a low detailed one with substantially fewer vertices for use on slower computers or for use in large assemblies. The low detailed model will still be dimensionally accurate.

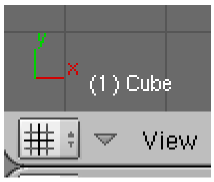


First of all, I think a brief description of what we are about to model and how we will go about it is in order. Its always better to plan what you are doing before you start, rather than leaving it to chance as you work through your ideas. This model won't be used to manufacture the bearings so I am only concerned with the internal diameter, external diameter and width of the bearing being accurate, the rest is open to some artistic interpretation.

The method to create the shell of the bearing will be to draw a cross section of the inner and outer race relative to the centre of the bearing and then spin this through 360 degrees.

We will work to a scale of one blender unit equals one millimetre. Nothing has to be set in blender to achieve this, just always remember for this tutorial every dimension you input is in millimetres.

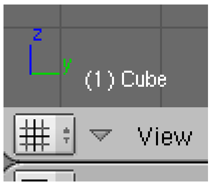
Keyboard and mouse actions will be shown in **bold** type



Open blender, you will be presented with the default top view looking down onto the top of a cube object. In the bottom left corner the co-ordinates arrows show the directions of the axis.

Press and hold the **MMB** (middle mouse button) and drag the mouse around to rotate the viewing direction, the other sides of the cube will then be seen. You can pan the view by holding down the **Shift** key whilst pressing the **MMB** and moving the mouse The top view can be reset at any time by pressing **NumPad-7** (Top View). If you loose your cube from the view you can retrieve it by pressing the **Home** key.

When we draw our bearing we need to orientate the model so the front face of the bearing is shown when we press the front view. The first part of the process is to draw a section through the bearing perpendicular to the front face, therefore we need to draw on the side view.



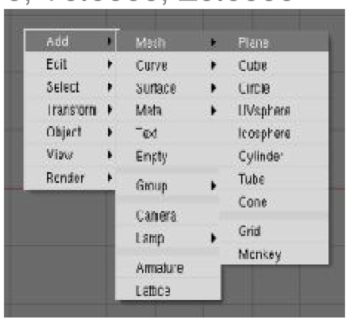
Press **NumPad-3** (Side View). The position of the cameras and light will change in the view and the co-ordinate arrows will change to reflect the different axes positions.

If you press **N** on the keyboard the Transform Properties window will open. This gives details of the location of the object within the 3D co-ordinates, the rotation around its centre point, any scale applied to the object and the size of its bounding box (box that encloses the object).

The red green and blue arrows in the centre of the cube object can get in the way when precision modelling. Press the hand icon on the Transform Properties panel of the view header.

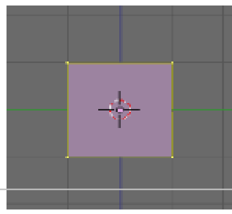
The options in the Transform Properties panel will change and the hand icon will turn white. The arrows will be removed from the view.

We need an object to build our model on but the cube isn't very useful for the bearing so we will delete it. Press the **X** key to bring up the delete menu and accept the pop up menu option. The cube will be removed from the screen leaving the cursor in the centre of the global co-ordinates. Cursor position X0.0000, Y0.0000, Z0.0000



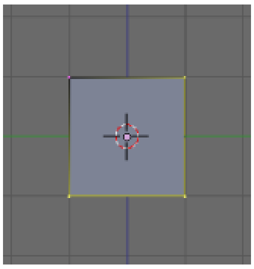
In order to draw our bearing we need an object with at least one vertex. For this we will insert a Plane.

Make sure you are still in side view **NumPad 3** then press the **Space Bar** to bring up the Toolbox, as we are adding a mesh object, move the mouse over "Add" a sub menu appears, move the mouse over "Mesh", another list of options will appear, click on "Plane".

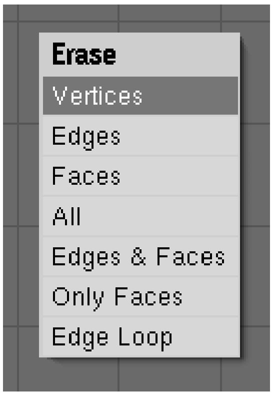


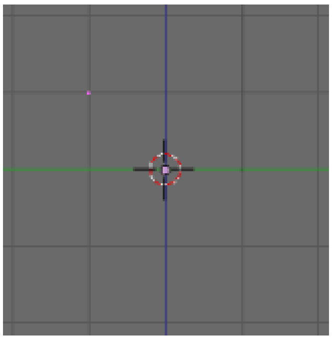
A Plane will be created, centred on the cursor and the view will have switched to Edit Mode to allow you to edit the plane.

As we need to work from one vertex centred on the cursor, press the **A** key to de-select all the vertices which will turn them grey and the edges black. Hold the **SHIFT** key to multiple select three vertices with the **RMB** (right mouse button).



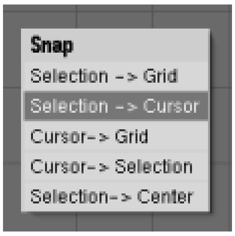
Press the **X** key to bring up the delete menu. In edit mode, there are more options available than object mode.





Select "Vertices" and the three selected vertices will be removed from the view along with the face and edges of the plane. A single vertex will remain in the view and the Planes object centre will remain centred on the cursor.

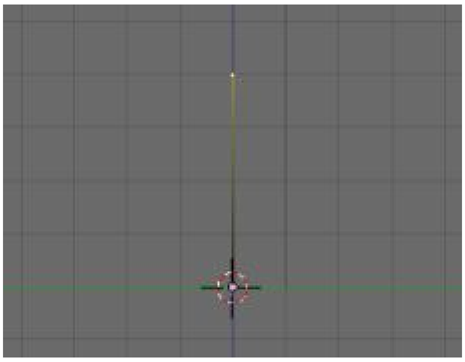
In Edit Mode you can undo any changes you make by pressing **Ctrl-Z**



With the **RMB** click on the remaining vertex to select it, it will now turn yellow. We need to snap this vertex to the cursor position

Press **SHIFT-S** together to bring up the snap menu and select, Selection>Cursor. The vertex will now snap to the cursor position, however it can't be seen as the object centre hides it.

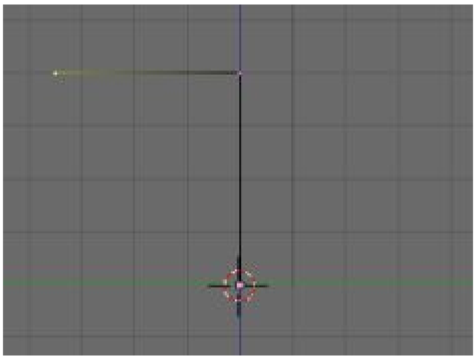
A 608 bearing has an inside diameter of 8mm therefore if the object centre is on the centre axis of the bearing we need to position the inner race 4mm from the object centre.



Press **E** to extrude the vertex then press **Z** to constrain the movement of the vertex to the Z-axis then press **4** the vertex will extrude 4mm along the axis. Press **Enter** to accept the move.

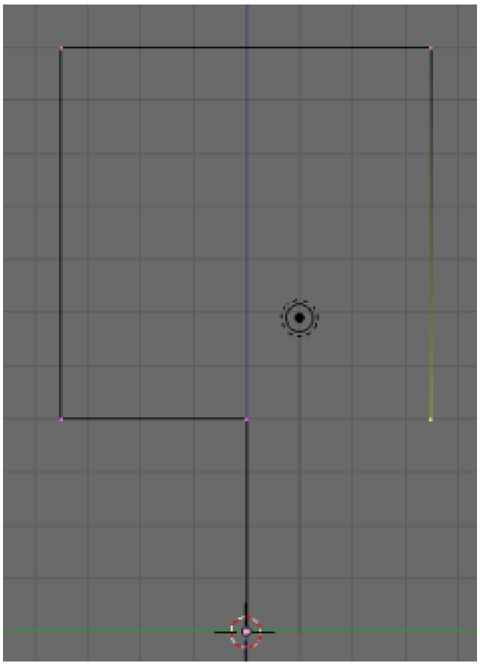
An edge has now appeared coming from the object centre to the mid point of the inner race.

The width of a 608 bearing is 7mm so from the centre point we need to extrude an edge 3.5mm along the Y-axis.



Press **E** to extrude, **Y** to constrain it to the axis, **-3.5** to set the position 3.5mm along the negative Y-axis and **Enter** to accept.

The second edge will now have appeared.



Repeat the extrude process for the other sides of the bearing.

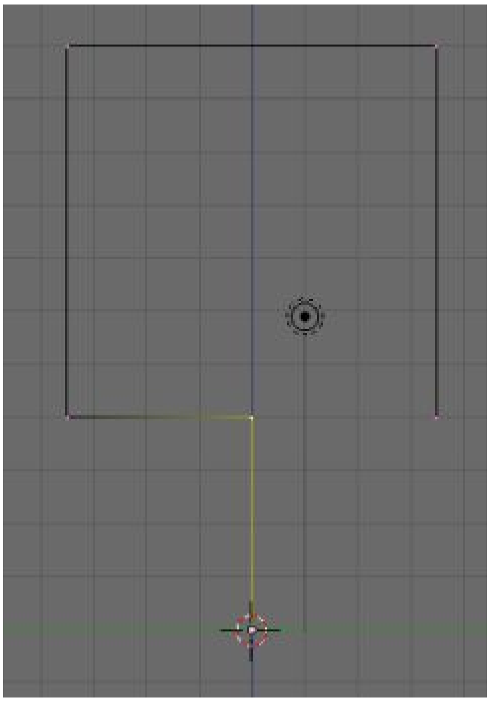
The dimension between the inner and outer race is 7mm so:

Press **E** to extrude, **Z** to constrain **7** to position and **Enter** to accept.

Extrude the outer diameter 7mm along the Y axis.

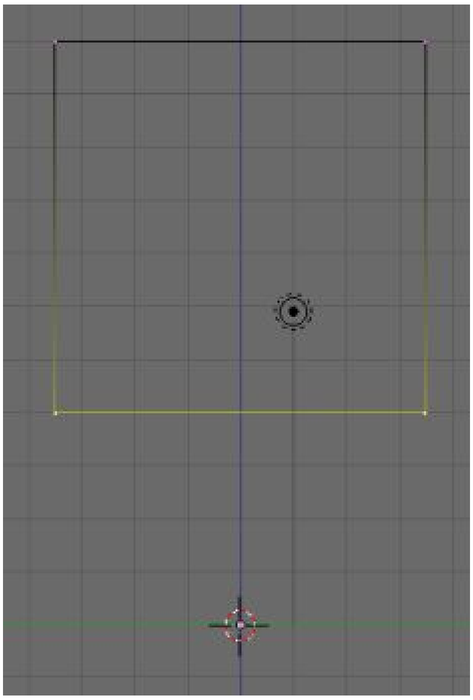
Extrude the other side of the bearing -7mm along the Z axis.

You should now have the shape opposite in your view.



With the **RMB** Select the vertex under the cursor and then **SHIFT-RMB** the vertex directly above, so both are selected. These are no longer needed so press **X** and delete Vertices

Select the two bottom vertices **Shift-RMB** and press **F** (face) to add an edge between them

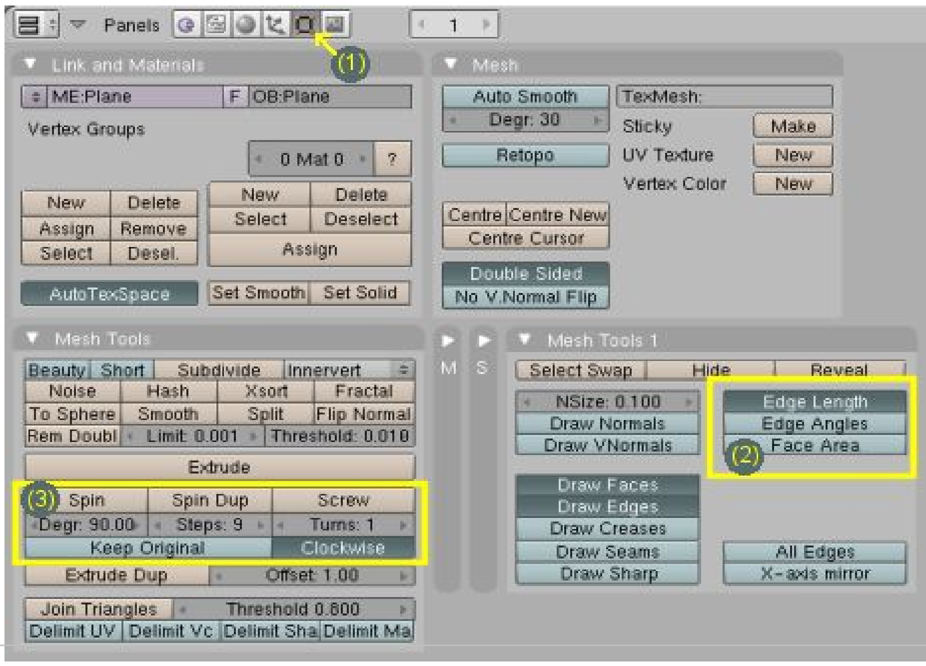


We have now created the reference geometry to construct the detailed cross section of the inner and outer race relative to the centre axis. Blender has the ability to show the length of any selected edge. To activate it go to the buttons window at the bottom of the screen.

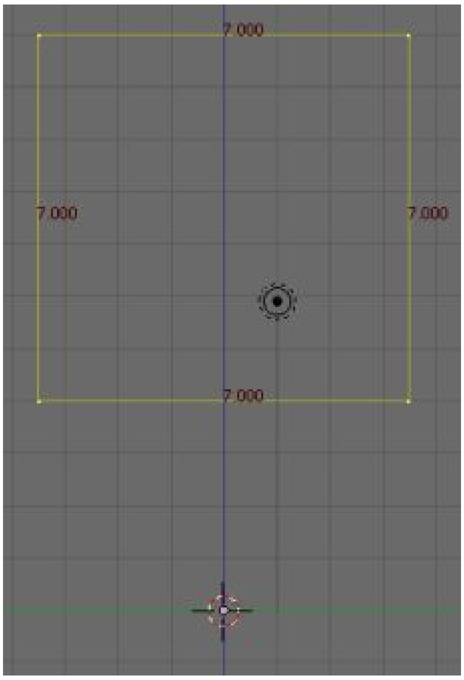
Click the Editing Context button (1) to bring up the edit buttons.

In Edit mode the buttons panels below will become available spread horizontally along the bottom of the screen. It may be necessary to drag the button panels to the left to see all the options. Pressing the **MMB** and dragging can do this.

In the Mesh Tools 1 panel (2) select Edge Length and the view will display the length of any selected edge.



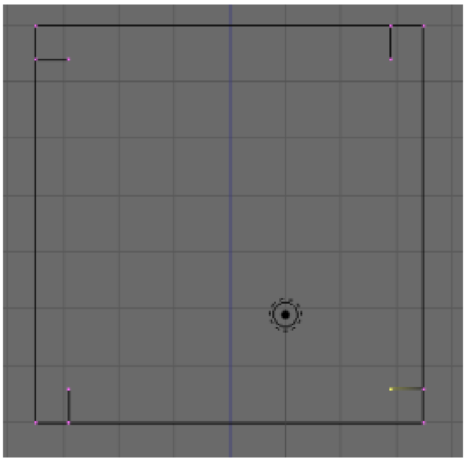
The bearing has a 0.6mm fillet on the edge of the inner and outer race. As Blender is not primarily a CAD program it doesn't yet have a dedicated fillet tool. However it is both quick and simple to add a fillet using the Spin function (3) in the Mesh Tools Panel



First we need to add a vertex at the start point of the fillet and also at the centre of the fillet. The spin tool works in the clockwise direction so it is important to take this into account when positioning the first vertex.

Starting in the bottom left corner, select **RMB** the corner vertex. Press **E** to extrude, **Y** to constrain to the Y-axis, **0.6** for the length and **Enter** to accept. This has created the fillet start vertex. With the new vertex still selected, Extrude **E**, Constrain **Z**, and length **0.6** and accept **Enter**. The fillet centre has been created.

Repeat this sequence in the other corners.

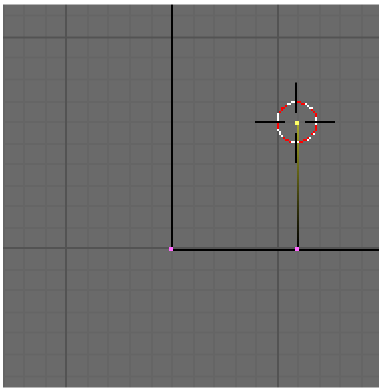


Select **RMB** the top left vertex, **E**, **Z**, **-0.6** and Enter. Then **E**, **Y**, **0.6** and **Enter**.

Select **RMB** the top right vertex, **E**, **Y**, **-0.6** and **Enter**. Then **E**, **Z**, **-0.6** and **Enter**.

Select **RMB** the bottom Right vertex, **E**, **Z**, **0.6** and **Enter**. Then **E**, **Y**, **-0.6** and **Enter**.

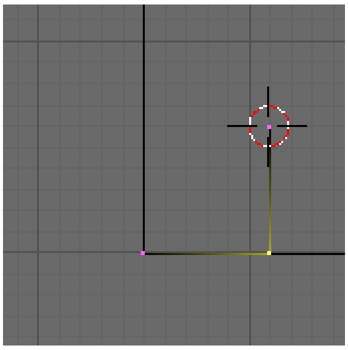
Your view should now look like the image opposite.



Starting in the bottom left corner select **RMB** the vertex on the centre point of the fillet

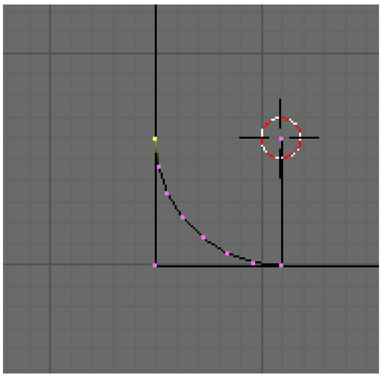
Press **Shift - S** to open the Snap menu and select Cursor -> Selection. The cursor will be positioned on the fillet centre.

Now select **RMB** the vertex that will be spun to form the fillet.



In the Mesh Tools panel make sure in the text box below the spin button Degr: 90 is displayed. Change the Steps: 9 to Steps: 7 as we don't need that many vertices to scribe the fillet. Clicking on the small arrow either side of the “Steps:” text box, or pressing **Shift** and clicking over the number with the **LMB** (left mouse button) can alter the number. You can then use the keyboard to enter the number.

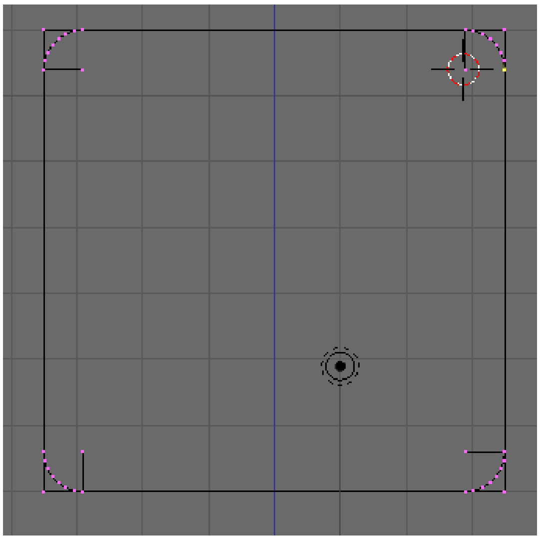
Press the Spin button and the first fillet will be created.



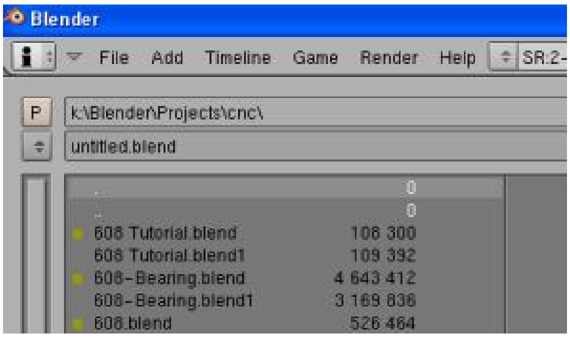
Repeat the process on the other corners

Select **RMB** centre vertex. **Shift-S** cursor->Selection. Select **RMB** the vertex to spin. Press Spin in Mesh Tools panel.

The vertices of the fillets are the first part of the bearing section that we will keep; the other edges are only there as drawing aides and will be removed later.



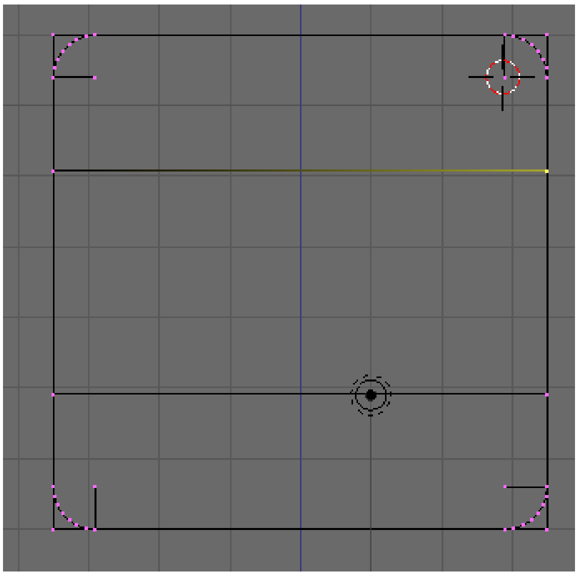
We now have the Inner diameter, outer diameter and width of the bearing cross section positioned accurately above the centre axis, together with the corner fillets. The four corner vertices and edges we have created are only reference points, which we will use to position the detail needed for the inner and outer race.



This is a good time to save your work. Blender handles this slightly different to other programs, a good description of the process can be found on the Blender Wiki. For now though press File - Save As. The 3D view will change to the File window. Choose the folder where you want to save your file and name it as 608-Bearing.blend Click Save File and the screen will change back to the 3D Window.

When you first use blender it may seem this is a slow and cumbersome way of drawing, but as you get used to the concept and the keyboard short-cuts become instinctive it is extremely fast. I have timed myself and from clicking the Blender icon on my desktop to load blender, to reaching this stage takes less than two minute’s. This is about the same amount of time it takes just to load the CAD package on my works CAD machine.

With the corner fillets in place it's now time to define the inner and outer race.



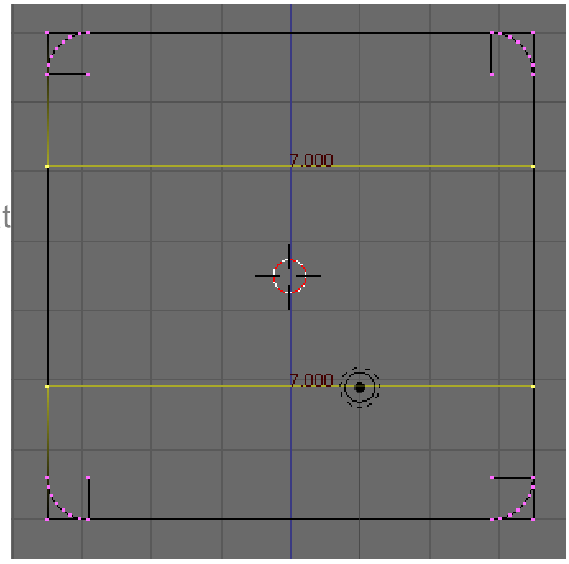
The thickness of each race is 1.92mm, so we need to divide the cross section accordingly.

(You should now know the keyboard commands to select, extrude and constrain vertices to a set axis, so from now on I will only include the commands for these operations occasionally.)

Select the bottom left vertex and **E**xtrude it on the **Z**-axis **1.92**mm. Then extrude this vertex 7mm in the Y axis.

Select the top left vertex and extrude it -1.92mm in the Z-axis. Then extrude this 7mm in the Y-axis.

The thickness of the Inner and outer race is now defined.

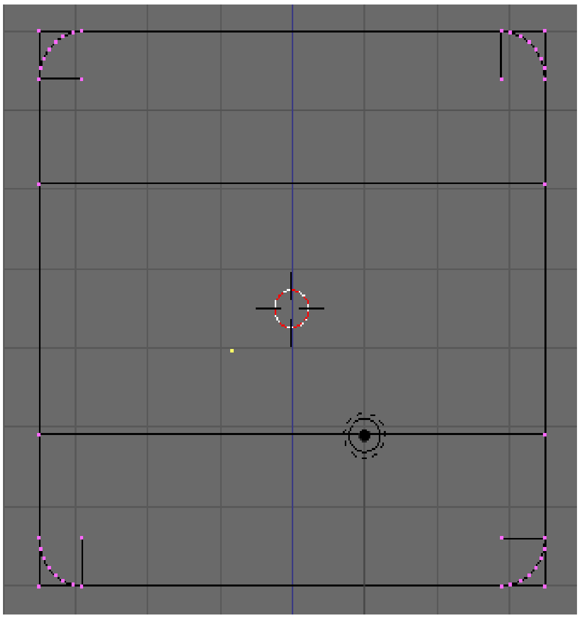


The next stage is to form the grooves that the ball bearings will run in. To do this we must spin a circle from the centre point of the two bearing races.

Hold **Shift** and Select **RMB** the four vertices that are on the ends of the two edges that we have just created to define the thickness of the inner and outer race.

Press **Shift-S** and snap the cursor to the selection. Because we have selected more than one vertex the cursor will snap to the centre of all the vertices.

We now need to snap a vertex to the cursor. To insert a vertex, ensure nothing is selected **A** and holding the **Ctrl** key click **LMB** anywhere near the cursor. A new vertex will be created.

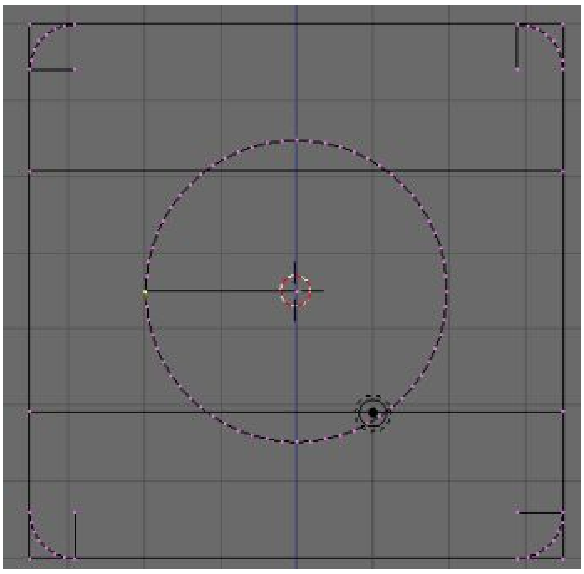


Snap the vertex to the cursor. **Shift-S**, Selection->Cursor.

The Ball Bearings have a diameter of 3.95mm so we need to spin a radius of 1.975mm.

Extrude the vertex -1,975 on the Y-axis.

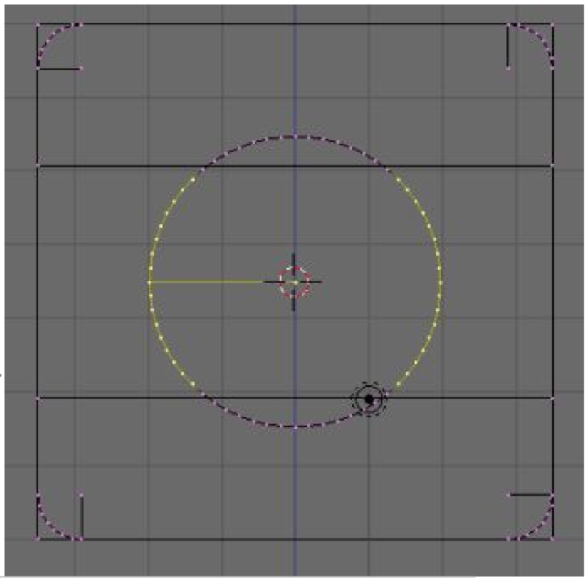
In the Mesh Tools panel set Degr: to 360 as we are going to spin a complete circle. Set Step: to 64. This will give us a sufficiently detailed circle.



Its worth noting that if possible you should always choose a number of steps that will give a vertex on each of the circles quadrants.

With the vertex we have just extruded still selected spin the circle.

Excluding the vertices whose edges intersect the line defining the inner and outer race, the centre vertices are no longer required and can be deleted.



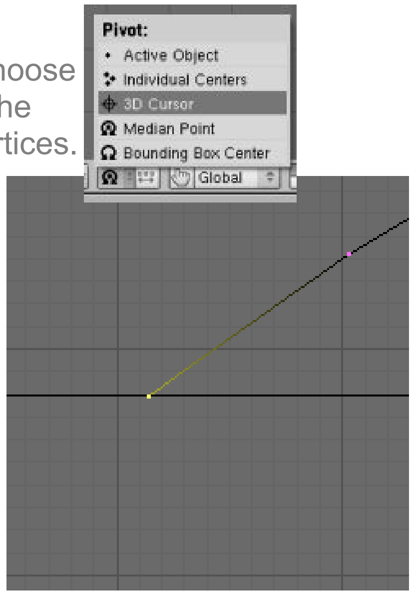
Rather than Shift-RMB selecting all the vertices Blender allows you to box select a group of vertices. To do this press the **B** key, the mouse pointer will change to a cross hair. Position it above and to the left of the vertices you need to delete. Press and hold the **LMB** and drag the cross hair to the lower right of the vertices to be deleted, release the **LMB**. The vertices within the selection box will now be selected.

Press **X** and Delete the vertices.

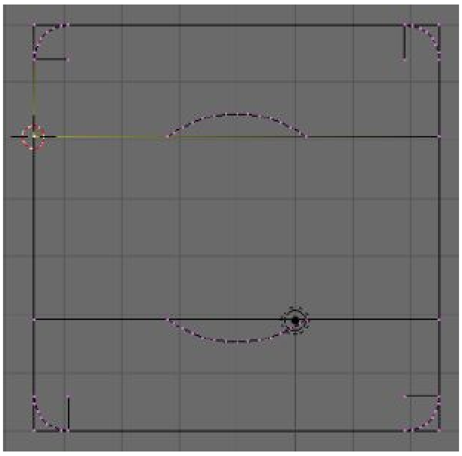
Until now we have been working with the pivot set to Median. This means that if you rotate or scale a group of vertices the centre of the rotation or scale will be the centre of the selected vertices.

To align the end vertices of the bearing grooves we need to rotate individual vertices around the centre of the ball bearing.

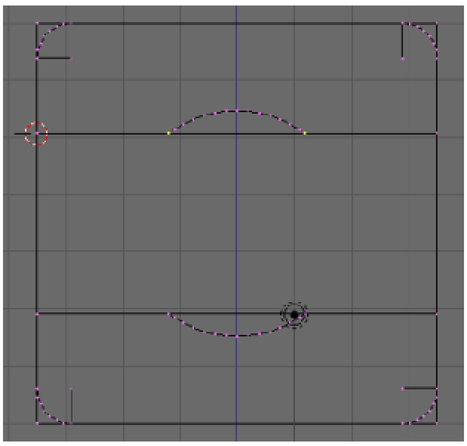
On the view header click on the pivot button and choose 3D Cursor. As the cursor is already positioned on the centre of the ball bearing we can rotate the end vertices.



Zoom in on one of the end vertices by rotating the **SW** (scroll wheel) and panning by pressing **Shift** and holding the **MMB** whilst moving the mouse. To rotate the vertex press **R** and drag the vertex until it is over the line defining the inner portion of the bearing race. Click the **LMB** to accept the rotation. Repeat this on all four vertices

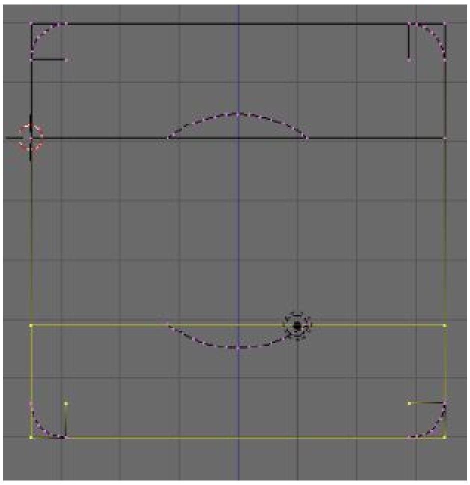


The vertices we have just rotated will be close to the edge defining the inner surfaces of the bearing race but not exactly on it. To correct this we will position the cursor on the inner surface edge. Select a vertex on the edge and **Shift-S** Cursor->Selection.

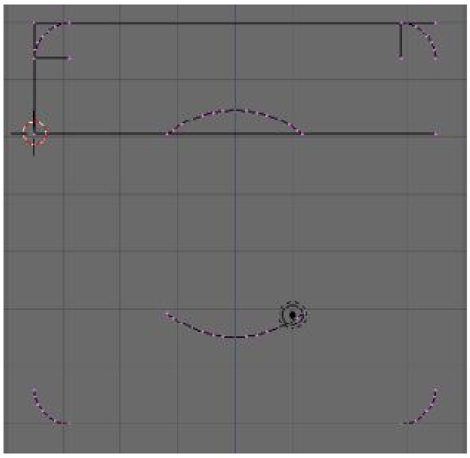


Then scale the two vertices onto the edge. Press **S** to scale **Z** to constrain the movement to the Z-axis and **0** to position the vertices in line with the cursor.

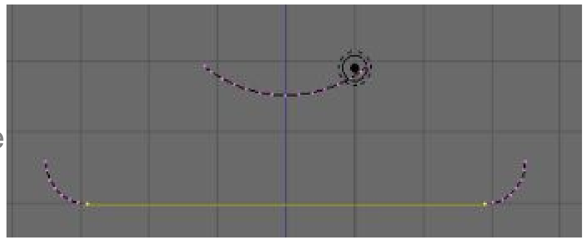
Repeat this on the other edge.



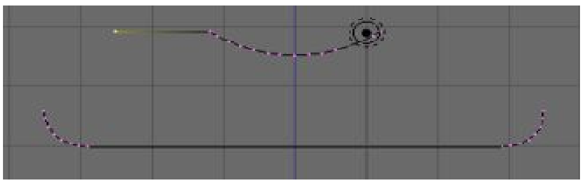
We now have enough detail to complete the inner race. Select the 6 reference vertices shown above and **X** delete them



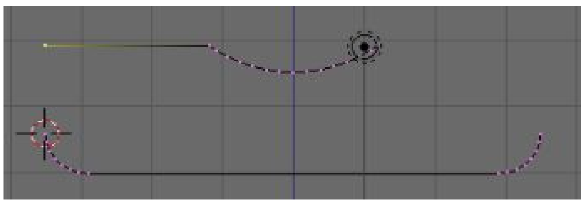
We are left with the two corner fillets and the bearing groove.



To reconstruct the face of the bearings inside diameter select the inner most vertices on the bottom fillets and press **F** to insert an edge.

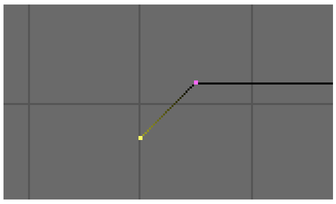


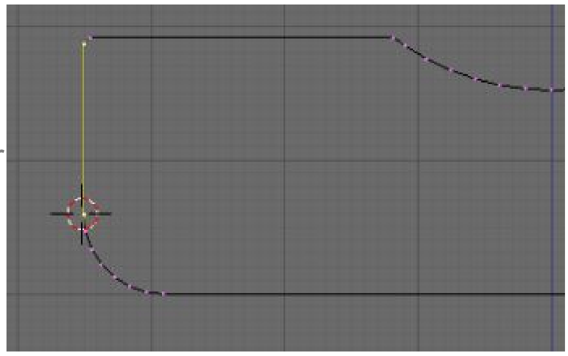
Extrude the end vertex of the bearing groove and constrain to the Y-axis



To align this to the outer edge of the bearing snap the cursor to the top vertex of the fillet. Re-select the extruded vertex and scale **S** constrain to the **Y**-axis and **0** to set its position in line with the cursor.

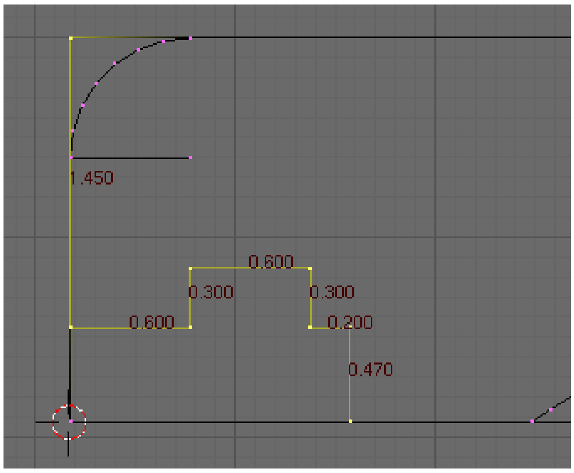
The inner edge of the inner race has a 0.05mm chamfer. To form this press **G** to grab the vertex (move), **Y** to constrain, **0.05** to set its position. Now extrude this vertex -0.05 in the Y-axis then grab **G**, constrain **Z**, **-0.05** to position. The chamfer is now formed.





Finally join the chamfer to the fillet with an edge. Select the end vertices on the chamfer and fillet and **F** to insert a new edge.

Repeat this on the other end to complete the section of the inner race.

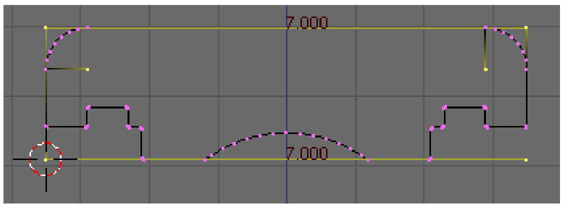


The outer race is a little mode difficult as it contains a circlip groove and location for the dust shield.

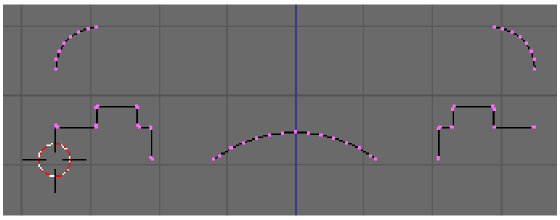
The creation of this form is fairly straightforward. From the top left corner vertex simply extrude and constrain the movement to the Z and Y-axis at the dimensions opposite.

Once completed repeat this on the other end of the bearing.

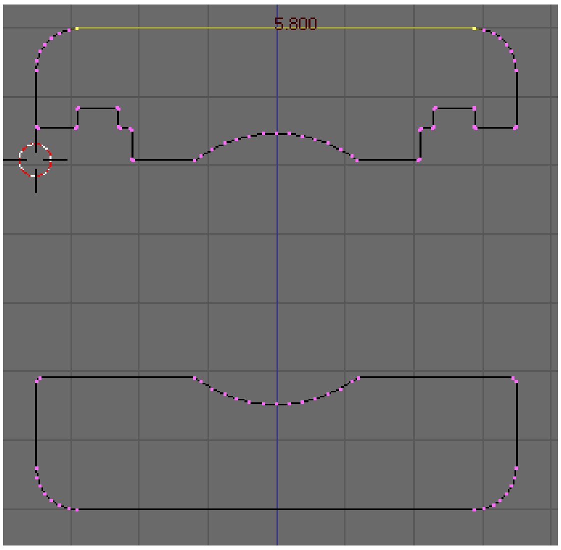
Once the edges are in place you can refine the cross section by adding a 0.02mm chamfer on each of the corners. This can be achieved by deleting one edge, extruding the end vertices 0.02 in the direction of the deleted edge, reinserting the edge and then moving the corner vertices 0.02 in the perpendicular axis.



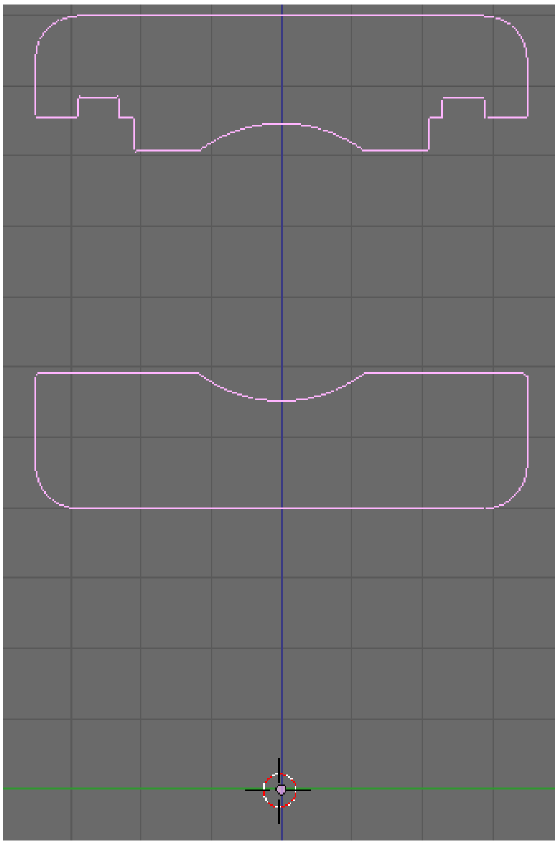
Delete **X** the six vertices used as reference points.



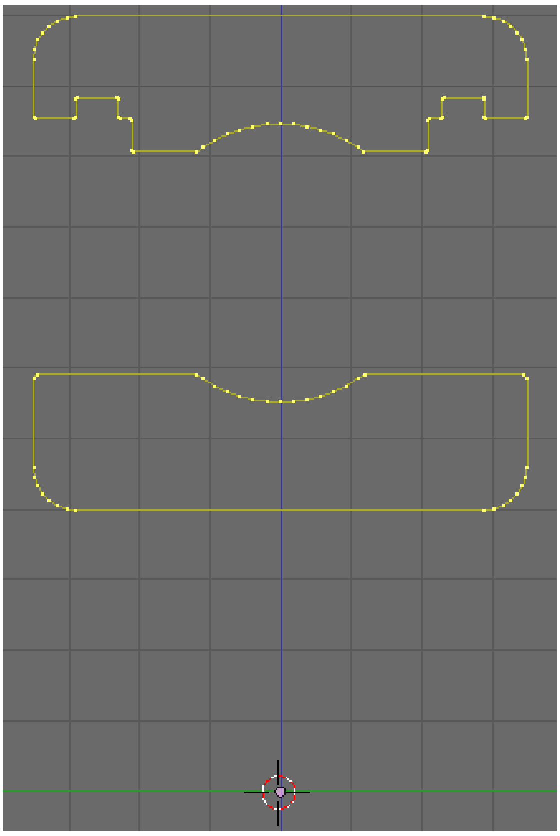
The basic shape of the outer race is now constructed. Select the vertices both ends of a gap and press **F** to insert an edge. Do this one edge at a time until the outer race is complete.



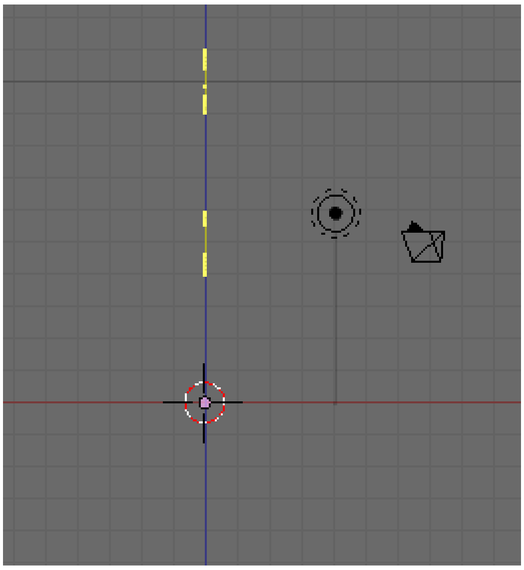
The section through the bearing is now complete and we are ready to spin this through 360 degrees to form the 3D model. However the spin process rotates around the cursor and it is currently in the wrong position. When we started to construct the section we worked from the Object Centre which defined the centre axis of the bearing.



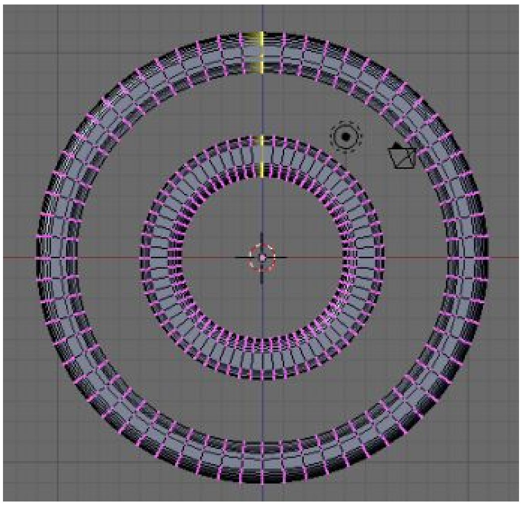
To snap the cursor to the object centre press **Tab** to go into Object Mode. From here you can press **Shift-S** Cursor->Selection The selection point of an object is the object centre.



Tab back into Edit Mode and press **A** to select all vertices.

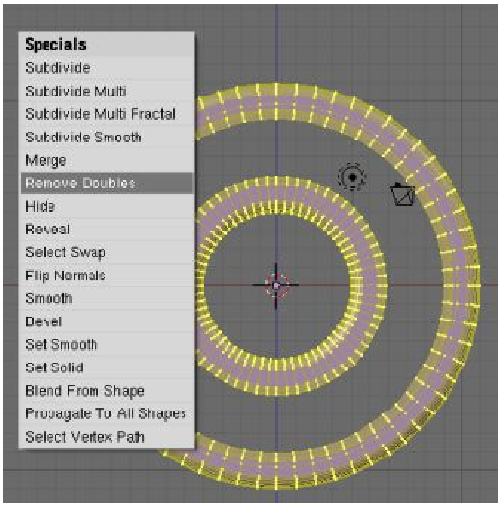


As we want to spin the bearing in the front view press **NumPad 1** and the view will change with the vertices lined up above the cursor.

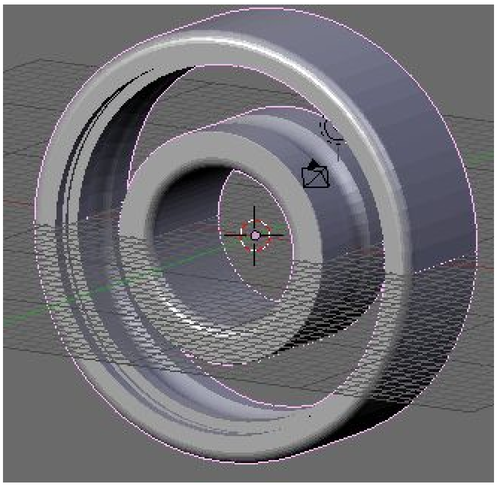


In the Mesh Tools panel check Degr: is set to 360 and Step: is set to 64. Press spin. The bearings inner and outer race will be formed.

The last set of vertices created will now be selected but they aren't yet connected to the first set of vertices.



To join these press **A** twice to select all the vertices then **W** to bring up the Specials menu, from this select Remove Doubles, which will merge any vertices that are sitting on top of each other.

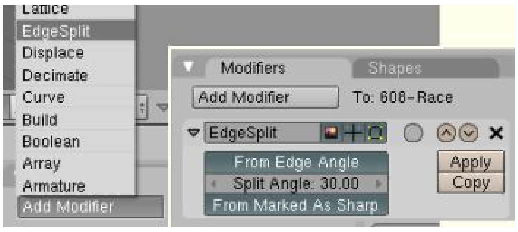


That's it for modelling the inner and outer race. Press **Tab** to go into Object Mode and rotate the view with the **MMB** to see the 3D view of the bearing from any angle. You can pan the view with **Shift-MMB** and moving the mouse.
If you loose your model from the view you can retrieve it by pressing the **Home** key

You will notice however that all the faces are flat with faceted edges to correct this in the view we will smooth the surfaces we need to appear round and retain edges we need to be sharp.

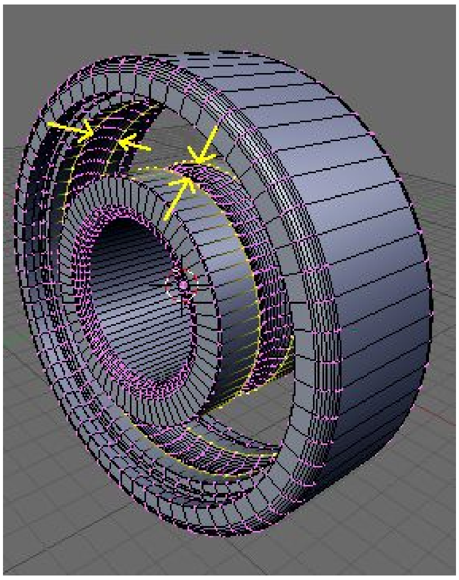
Tab back into edit mode and select all **A**. In the Link and Materials panel click "Set Smooth".

If areas of black appear on the surface of the bearing press **Ctrl-N** and accept "Recalculate Normals Outside". This will allow Blender to know which side of the faces are pointing to the outside of the object and which are on the inside.

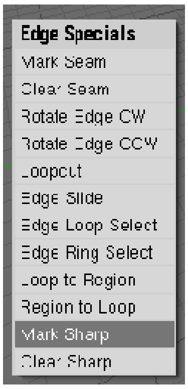


In the Modifiers panel press Add Modifier. From the pop up menu choose Edge Split. In the Edge Split modifier "From Marked As Sharp" and "From Edge Angle" will already be selected. Leave Split Angle:30. Which will smooth the join between any faces with an angle of 30 degrees or less. You will notice though that there is not a sharp edge between the bearing groove and the inner edges of the race because the angle is less than 30 degrees. This can be corrected by marking these edges for the Edge Split modifier to recognise as sharp.

Select the edge loops on the outer edges of the bearing groove. This can be achieved by first deselecting all vertices **A** and then selecting each loop **Shift-Alt-RMB**

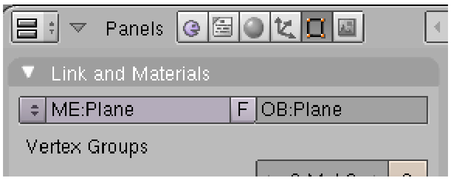


With the four loops selected press **Ctrl-E** to bring up the Edge Specials menu.



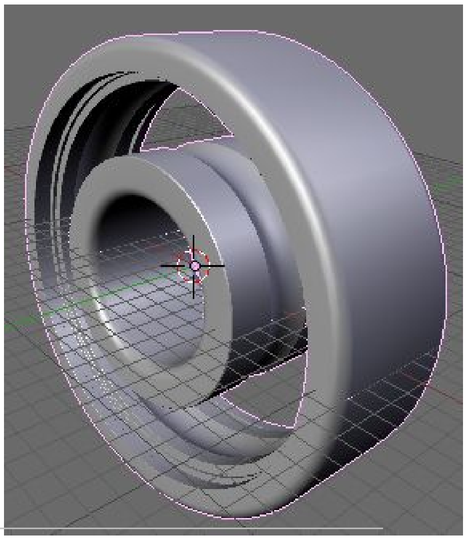
Select "Mark Sharp". This will tell the Edge Split modifier that these edges should be viewed as a sharp edge and it won't apply any smoothing to them.

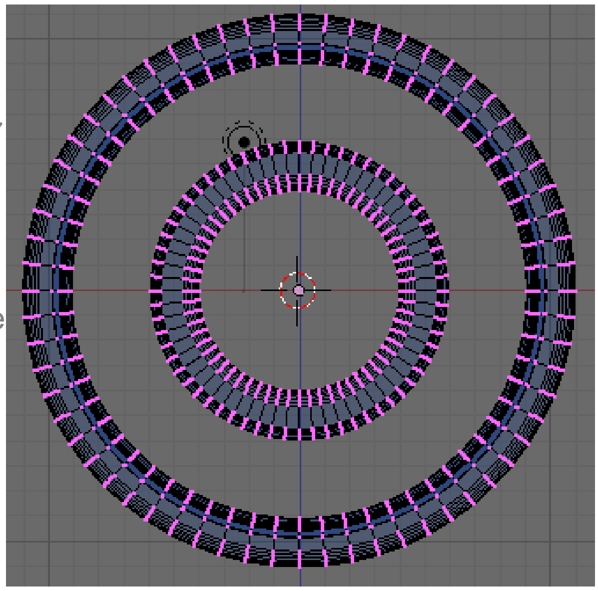
Before we create the next object we will give this one a meaningful name. In the Links and Materials Panel Click in the OB: Plane field



Delete plane and re name the object 608-Race

This is a good point to save your work. Press **Ctrl - W** and accept the save menu.

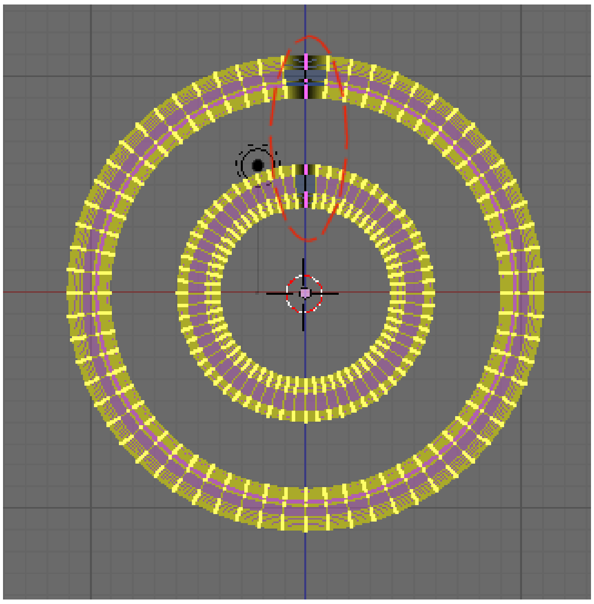




In Parts 1 and 2 we created the bearings inner and outer race, now we need to add some ball bearings. The 608 bearing has 7 balls so we will create and position one ball and then use a similar spin process to position the other six. This time though we will use "Spin Dup" to duplicate the selected vertices of the first ball around the cursor at the required step positions.

In front view **Num-Pad 1**, go into edit mode **Tab**, select wire frame **Z**, and de-select all vertices **A**.

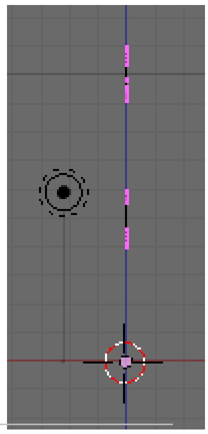
Before we insert a Sphere to use as the ball bearing we need to position the cursor central to the bearing groves of the inner and outer race. To do this we will hide all the vertices of the bearing race other than the perpendicular section directly above the cursor.



Press **B** (Box Select) and drag a selection box to select all the vertices to the right of the vertical centre line. Press **B** again and select all the vertices to the left of the centre line. Repeat this again to select the remaining vertices below the horizontal centre line. If you select the wrong vertices simply press **Ctrl-Z** to undo the selection.

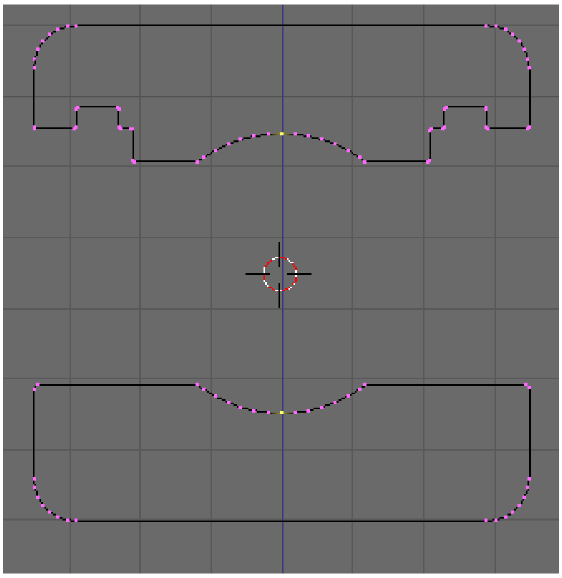
You should be left with only the vertices directly above the bearing centre deselected.

Press the **H** key to hide the selected vertices. The vertices haven't been deleted they are hidden so they don't clutter the view and cant be edited. You can retrieve these vertices at any time by pressing **Alt-H**.



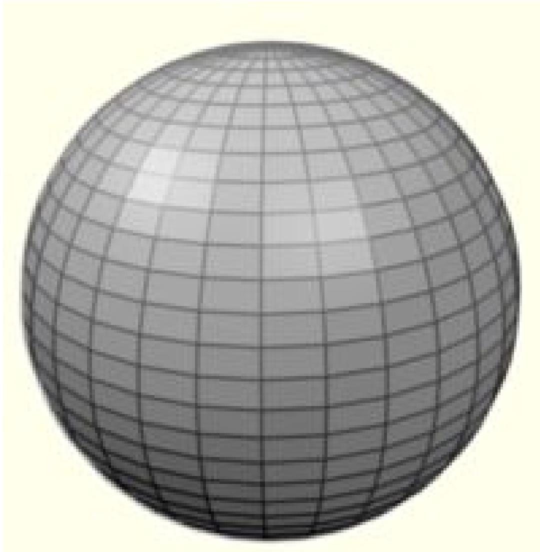
You will now have one row of vertices directly above the bearing centre.

Press **NumPad 3** to go into side view and select **RMB** the centre vertex of the inner race, bearing groove. Now add to the selection **Shift-RMB** the vertex directly above this on the outer race. The centre of these two vertices is the centre point for the ball bearing.



Press **Shift-S** to bring up the snap menu and select Cursor->Selection. The cursor will be positioned at the insertion point for the first ball.

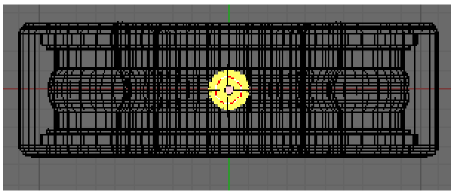
Un-hide the vertices we hid to make positioning the cursor easy by pressing **Alt-H**. Change to front view **NumPad 1** and **Tab** into Object Mode. You will see the cursor positioned between the bearing races directly above the Object Centre.

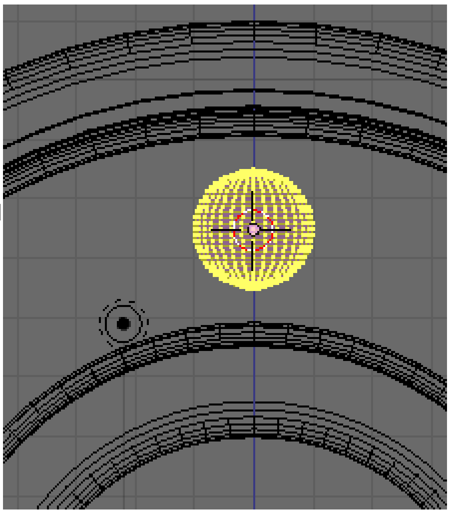


To form the ball we will use one of Blenders pre-set objects, the UV Sphere. The sphere is constructed from a series of latitudinal and longitudinal edges with poles at the top and bottom.

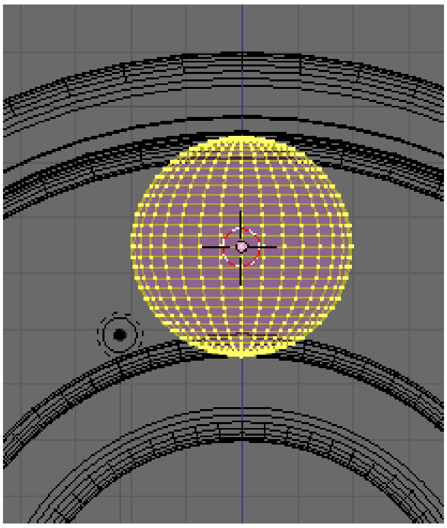
We will be using the geometry from the sphere to construct the bearing cage and it is important that it is oriented correctly. When we insert the sphere we need one of the poles to be pointing towards the bearing centre.

To achieve this it is necessary to insert the sphere whilst in the top view, so press **Num-Pad 7** for the top view and then press the **Space Bar** to open the Toolbox. select: Add > Mesh > UVsphere.





Accept the default 32 segments and 32 rings, a UV sphere will be inserted centred on the cursor with a diameter of 2mm. The mode will have switched to Edit Mode and all the vertices will be selected. If you click into front view **NumPad 1**, You will see the bearing is hanging in space and too small for the race. To correct this we need to scale the bearing.

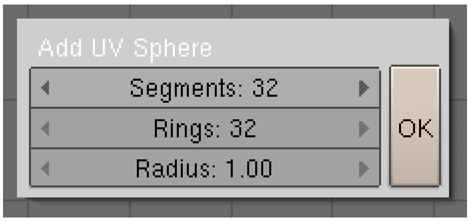


To obtain the correct scale factor, divide the required size of the ball by the inserted size of the UV sphere. As the balls are 3.95mm diameter and the UV sphere is 2mm then: 3.95 / 2 = 1.975.

Press **S** for scale **1.975** for the amount and **Enter** to accept. The ball now correctly fits the race.

Blender 2.44 Update

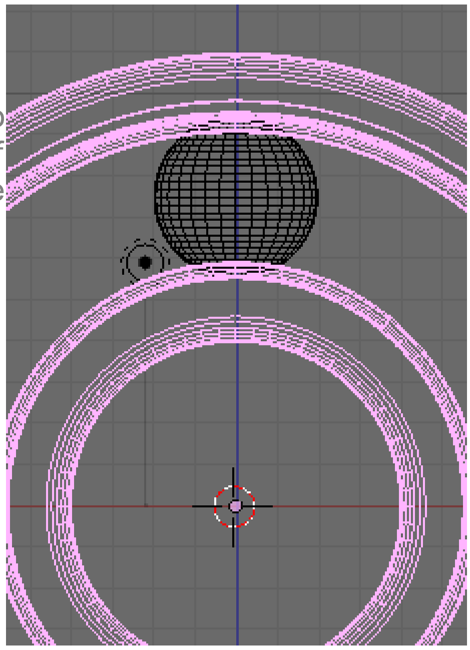
When you add a UV sphere there is a new floating panel that allows you to specify the radius, along with the segments and rings of the sphere. So you no longer need to calculate the scale factor when imputing some of the mesh primitives.



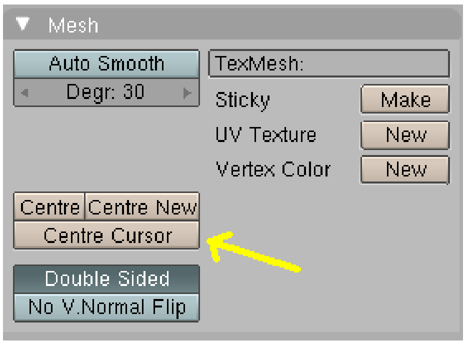
You can now simply hold down Shift and Click LMB over the radius figure and input the new radius of 1.975 and click OK. The UVsphere will now be inserted at the correct size.

Its still good to understand how to calculate a scale factor, as it will be needed in many other modelling situations.

The Object Centre for the ball is currently central to the UV Sphere and it would be much more useful if it was positioned central to the Bearing. To achieve this **Tab** into Object mode and select **RMB** the bearing race. Press **Shift-S** to bring up the snap menu and select cursor->Selection. The cursor will be repositioned to the centre of the bearing. Now reselect **RMB** the Ball



In the Mesh Panel there are three options for moving the cursor.



Centre: moves the object so it is centred over the Object Centre.

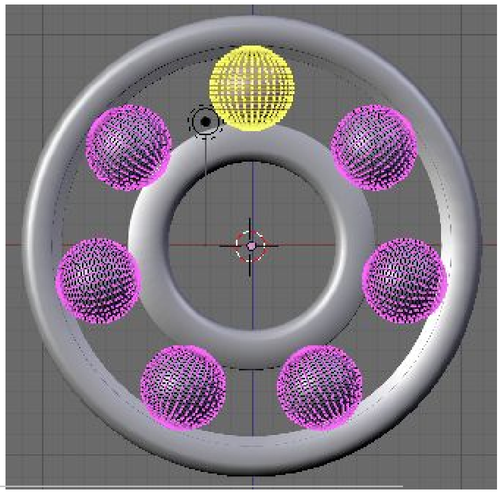
Centre New: Moves the Object Centre to the centre of the object.

Centre Cursor: moves the Object Centre to the cursor position, which is the option we require.

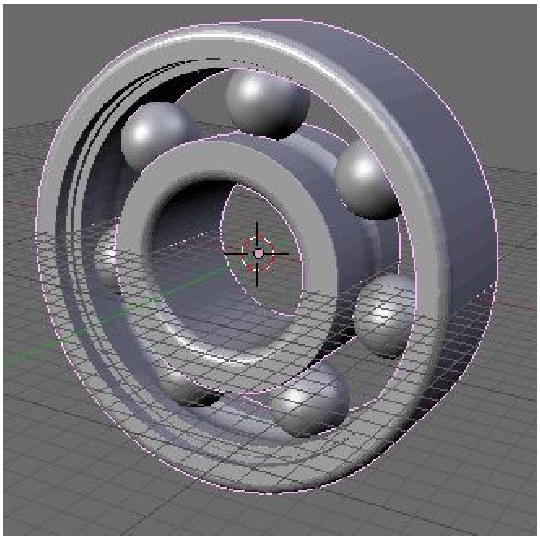
With one ball in place we now need to create the other six. As the cursor is on the bearing centre we can duplicate the first bearing 7 times around the race.

To achieve this **Tab** into Edit Mode.

In the Mesh Tools panel set the Deg: and Steps: as shown.



Press Spin Dup to duplicate the vertices seven times around the cursor. As with the spin command we have just placed a copy of the original ball over the top of the first one. To correct this select all vertices **A**, you will need to press it twice, once to de-select the last ball and then to select all. Press **W** (Specials Menu) and then select remove doubles.



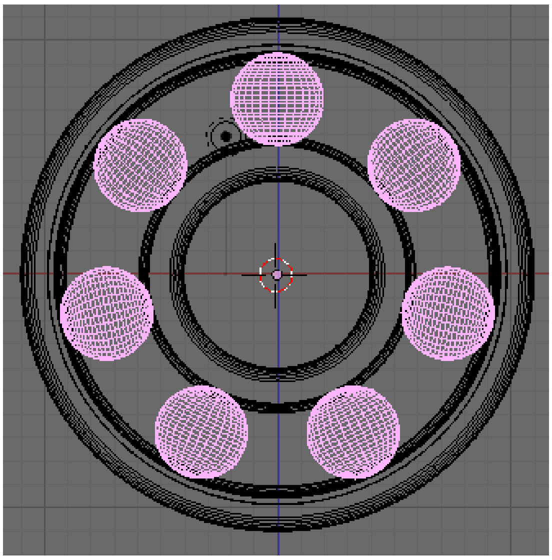
To change the appearance from the faceted surface of the UVsphere to a smooth surface, with all vertices selected click "Set Smooth" in the Links and Materials panel.

The balls are now created and positioned around the bearing. Press **Tab** to go into Object Mode, **Z** for solid view and rotate the view with the **MMB** to see the bearing as a 3D object.

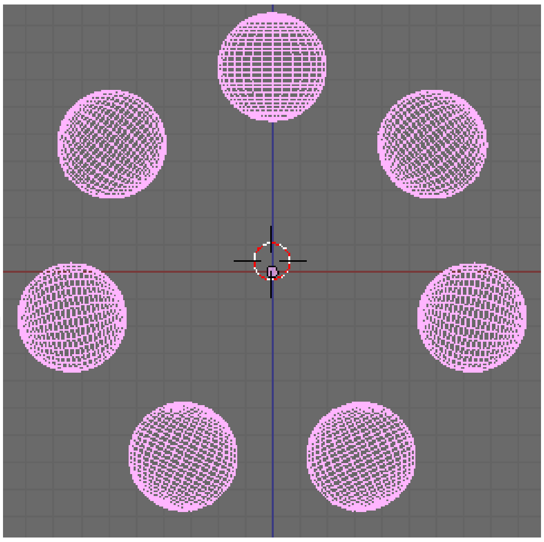
In the Links and Materials panel rename OB:Sphere to OB:608-Balls

If you haven't already done so press **Ctrl-W** and save your work.

Part 4 modelling the cage becomes a little trickier but as you get used to panning, rotating and zooming the view, selection of vertices and constructing models becomes a little easier to achieve.



When we inserted the UVsphere that formed the ball bearings it was important to ensure that one of the poles pointed to the centre. By doing this it has left us with the rings of the ball running perpendicular to the to the bearing centre axis and this allows us to extract the geometry from the surface of the UVsphere to form the inner profile of the bearing cage. This will become as little clearer as we work through this part of the tutorial.

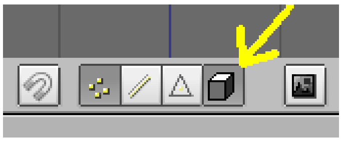


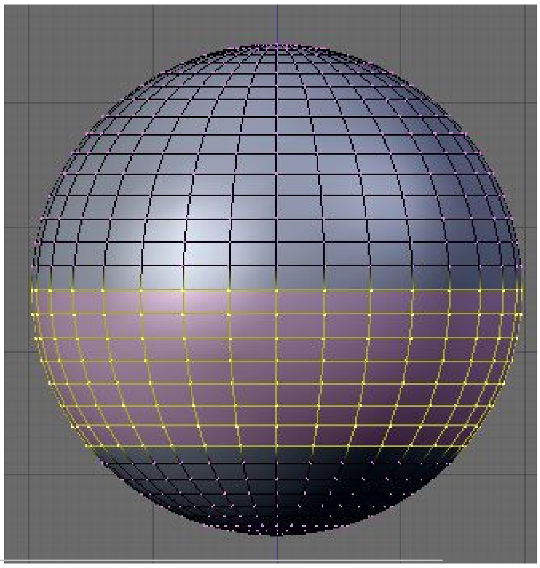
In front view select the balls, as the bearing race will get in the way of our view select local view **NumPad /**. This will remove everything from view except the selected objects.

With only the balls in view, zoom in and pan on to the top ball, **SW** (scroll wheel) to zoom, **Shift MMB** to pan.

Tab into Edit Mode and go into solid view **Z**.

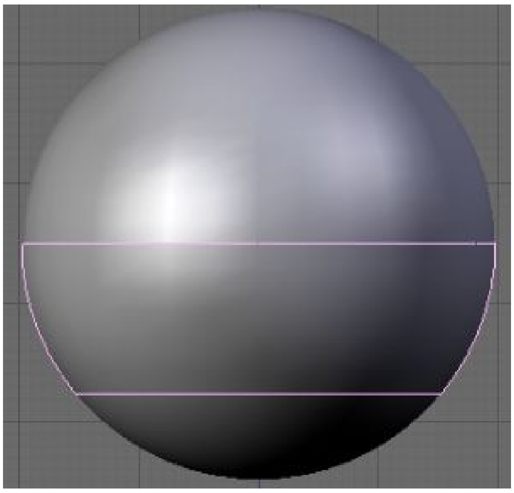
On the view header select the Limit selection to visible button, so you only select vertices from one side of the sphere. Without this being checked you would also select the unseen vertices from the back of the sphere.



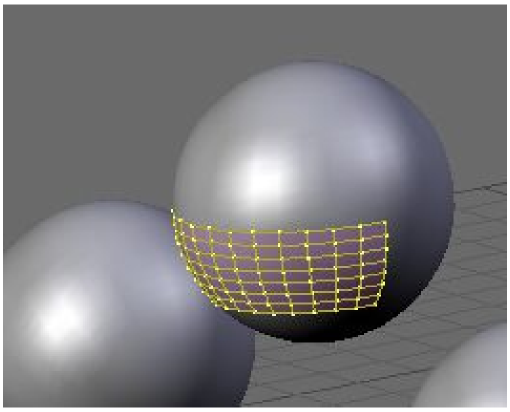


Box select **B** 8 rings of vertices starting from the centre ring and moving towards the bottom of the sphere. We will copy these vertices and turn them into a new object, they will then form the inner part of the bearing cage.

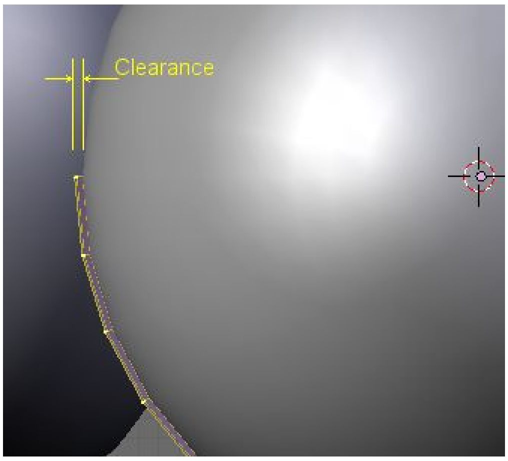
Press **Shift-D** to copy the vertices, then press **Esc** so they aren't moved from their original position. A new set of vertices has been created on top of the sphere. With these still selected press **P** (part) to separate them from the 608-Balls object. A new object has now been created and removed from the current Edit Mode selection.



Tab into Object mode and though not visible the new cage object is on top of the top UVsphere. **RMB** click over the cage and its outline will be highlighted. **Tab** back into Edit Mode.

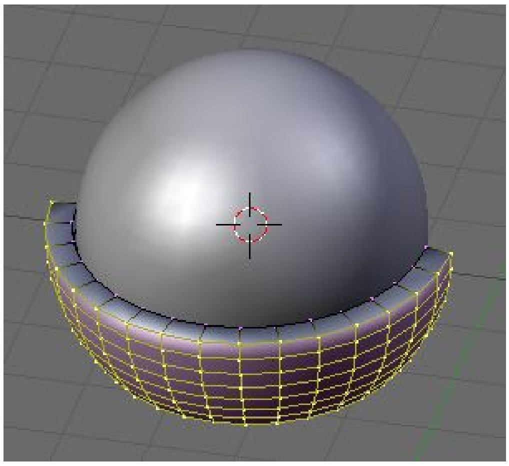


Currently the vertices of the cage are sitting on the surface of the ball which would stop the bearing from turning, so we need to add some clearance. To achieve this we will scale the cage from the centre of the top ball bearing.



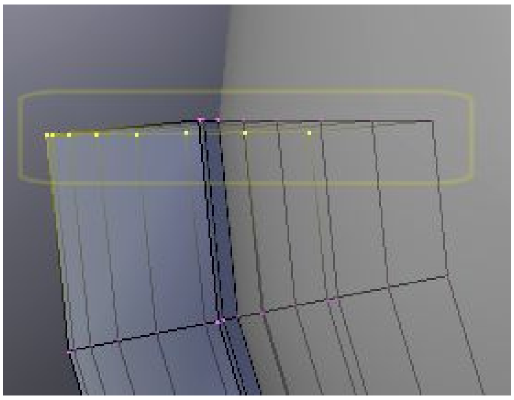
First we need to set the cursor at the centre of the top ball. **Tab** into Object Mode and select the 608-Balls Object. **Tab** into Edit Mode and de-select all **A** move the mouse close to a vertex on the top ball and press **L** (link select) this will select all the vertices directly linked by an edge to the vertex you are closest to. All the vertices of the top ball will now be selected. **Shift-S** and snap Cursor->Selection, this will centre the cursor on the top ball.

Tab back into Object Mode and select the Cage and **Tab** back into Edit mode. Make sure the Pivot Point is set to 3D Cursor and scale **S** the cage 1.02 This will give you a clearance of 0.0395 between the ball and the cage. ((Diameter * 1.02) - Diameter) / 2

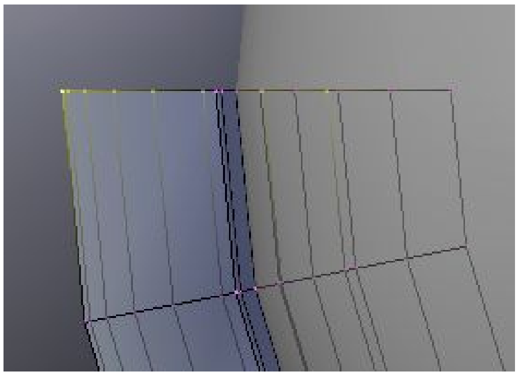


We have now got the inside profile of the cage but we need to add thickness to it. We could simply Extrude a new set of vertices and then scale them from the centre however we would need to work out a scale factor. Instead Blender has the ability to scale all faces in the direction of the face normals (see Blender Wiki for explanation of Normals). As we are scaling individual vertices then we only need to use the thickness as the scale factor.

With all the vertices selected extrude **E** select “Region” from the sub menu and then press **Esc** so the new vertices don't change position. Press **Alt-S** to scale along normals and **-0.3** for the thickness then press Enter. The cage is now 0.3mm thick

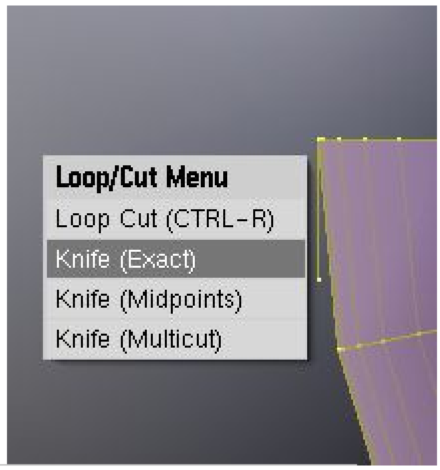


As we have created the thickness of the cage by scaling in the direction of the faces, the new end vertices are no longer on the centreline of the bearing. With the cursor still on the centre of the top ball and Pivot set to 3D cursor, select the new end vertices (you will need to deselect the "Limit selection to visible" button or go into wire view Z) **Shift-RMB** and scale **S** in the **Y** axis to **0**.



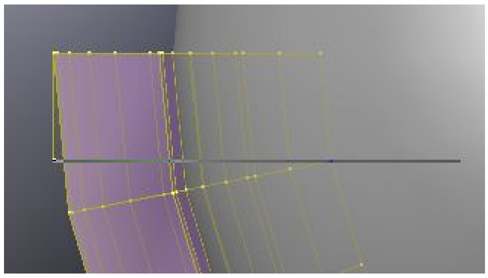
It may be easier to select all the end vertices of the cage as those that are already on the centreline won't move. Box Select vertices within the area outlined above then with pivot in 3D Cursor, Scale Y-axis to 0)

We now have the cage form that surrounds the bearing but if we Spin Dup this we will still be missing the section that bridges between this ball surrounds. Therefore before we Spin Dup this section we need to locate vertices so the bridging section when formed is 0.3mm thick.

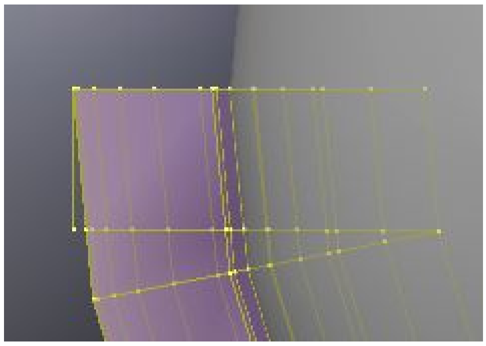


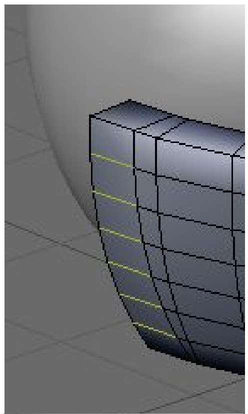
In top view select the outer most vertex and extrude it -0.3 in the Y axis. This vertex will be the reference point to cut a new row of vertices.

Select all **A** and press **K** (knife) a sub menu will open select Knife (Exact). The mouse icon will change to a knife. Move the knife close to the reference vertex and holding down **Ctrl** click with the **LMB** the cut line will be snapped to the reference Vertex.

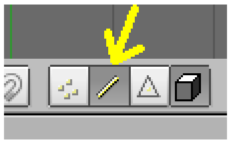


Drag the line to the right and click **MMB** this will constrain the cut to a line running horizontally along the view, which is the X-axis. With the line passing all the edges of the left side of the cage click **LMB** to set the line and then **Enter** to cut new vertices.



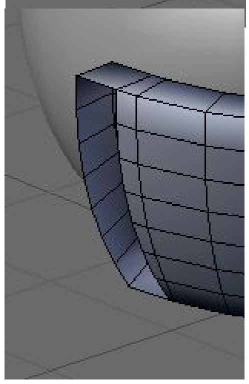


Repeat the cut on the other end of the cage, then delete X the reference vertex.

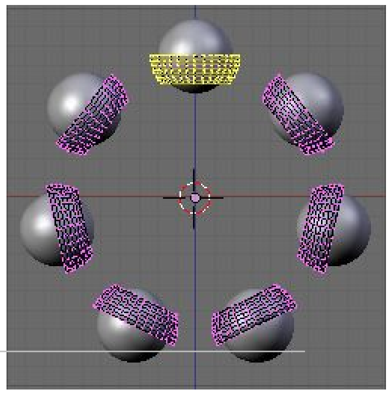


We now have a row of vertices running parallel with the back face of the cage at 0.3mm. We will need to delete the faces and edges between this new row and the back edge. To make selection easier go into Edge Select.

Select **Shift-RMB** over the 6 edges indicated and delete **X** selecting Edges from the delete menu. Repeat this on the other end.



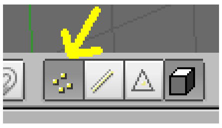
The cage profile should now have a row of faces missing on either end. When extruded and joined to the next cage profile, this will allow us to have a continuous shell without any faces or edges inside the model.

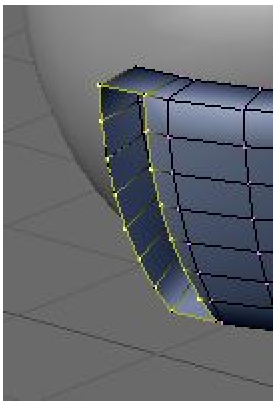


As the cage has been created from the 608-Balls Object, its object centre is on the bearings centre axis. **Tab** into Object Mode and snap **Shift-S** the cursor->Selection to centre the cursor on the bearing axis. **Tab** back into Edit Mode and select all vertices **A**.

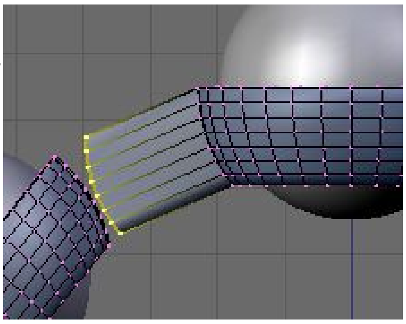
In the Mesh Tools panel set Degr: 360 and Step:7 and Spin Dup the vertices. Select all vertices **A** and remove doubles **W**

Click back into vertex select mode.



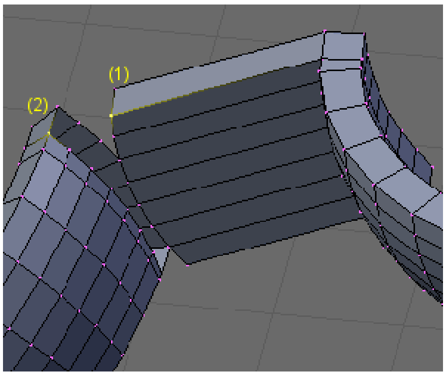


We now have 7 cage profiles that need to be joined together. Zoom in on the top profile and select the loop of vertices around one of the open ends **Alt-RMB**

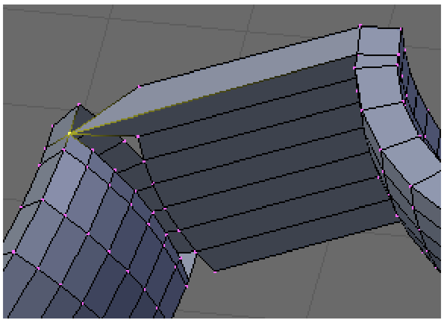


In front view, extrude the selection **E** and accept Only Edges from the sub menu. Drag the extruded vertices towards the next cage profile.

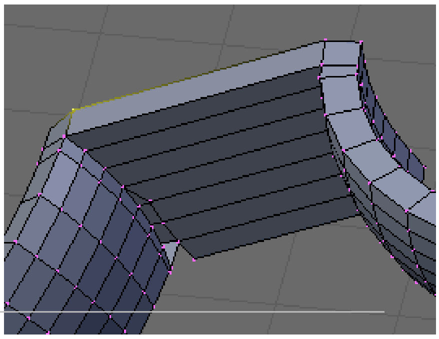
We now need to merge the extruded vertices onto the next cage profile.



To do this select one vertex on the extruded edge (1) then Shift select the corresponding vertex on the next cage profile (2). Press **Alt-M** to open the Merge sub menu and select "At Last". This will join the vertices at the position of the last selected vertex.

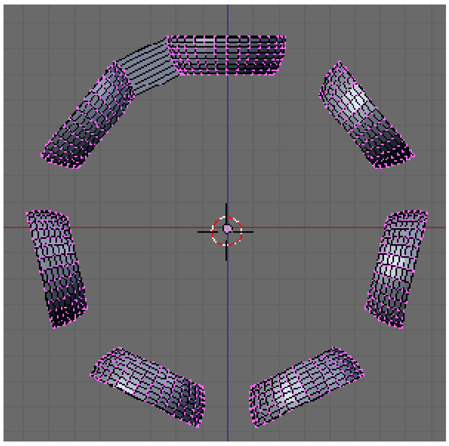


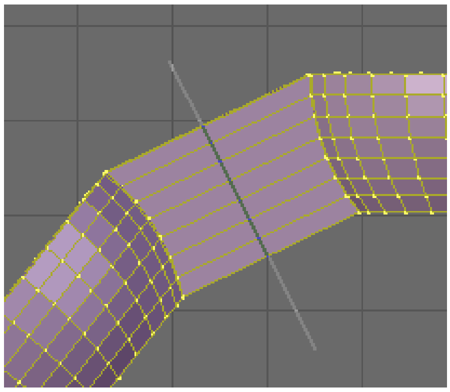
Repeat this for all the vertices around the loops to be joined.



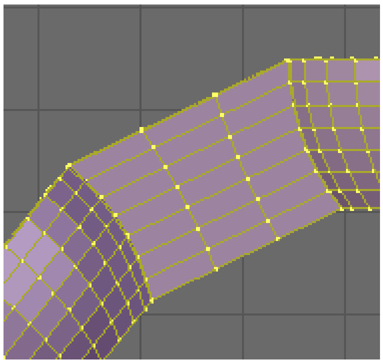
We now have two cage shells joined together with a connecting bridge all with a thickness of 0.3mm.

Soon we will mirror this cage to form the cage on the other side. But before this a little more geometry is needed, as the two half cages are joined together with a folded tab over the outer circumference of the cage.

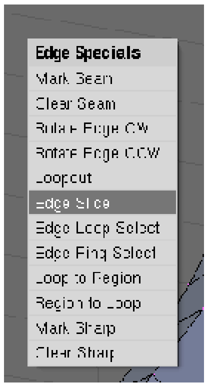




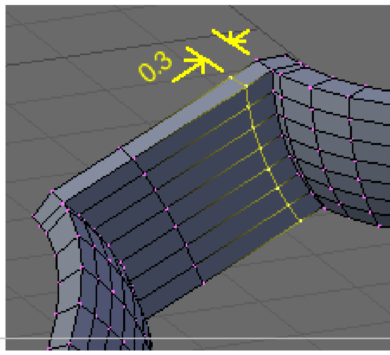
To create the vertices that will eventually form the joining tab, select all **A** and cut through the bridging section **K** but this time accept Knife (Multicut) from the Cut Menu. A new sub menu will open allowing you to choose the number of cuts. Accept the default 2.



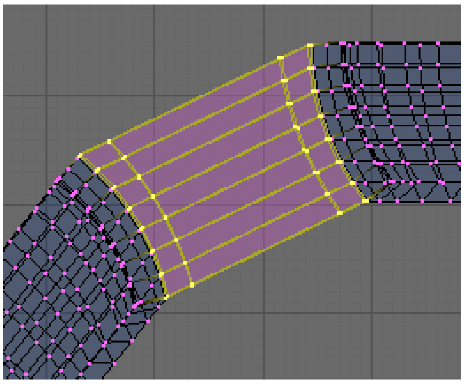
Two new edge loops will be formed on the bridging section, but not in the position we require them in.



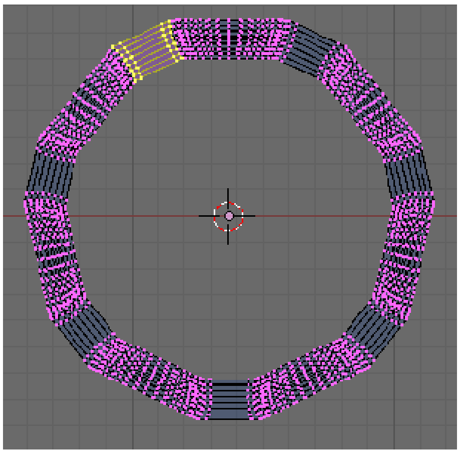
To reposition the vertices we will use Edge Slide to slide the loops of vertices towards the cage sphere profiles. **Alt-RMB** select one loop and turn on "Edge Length" in the Mesh Tools 1 panel.



Press **Ctrl-E** to open the Edge Specials menu and choose "Edge Slide". Slide the loop of vertices until the top vertices are 0.3mm from the cage sphere profile as shown above. Whilst moving the loop you can press **Shift** to give finer control of the movement.

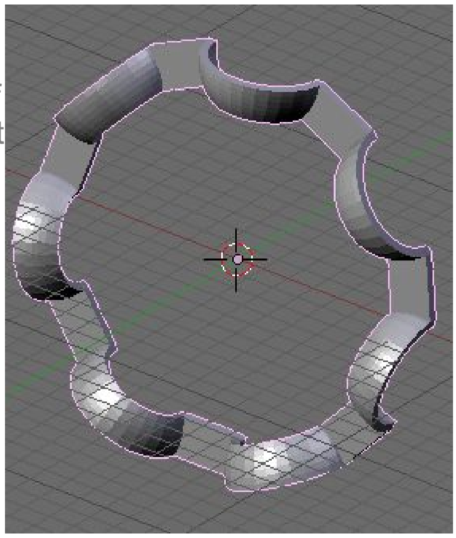


With the two edge loops slid to a position 0.3mm from the cage spheres select the vertices of the bridge section. (The two edge slide loops and the two loops connecting the bridge to the sphere.



Ensure the cursor is still on the bearing centre axis and Spin Dup the selected vertices. Degr: 360, Step:7.

Select all and remove doubles.



You have now made the basic construction for one half of the cage. We will chamfer the edges of this but first we need to copy and mirror this object to make the other half of the cage.

In the Links and Materials panel change the Objects name from OB:608-Balls.001 to OB:608-CageA, the previous name was automatically assigned by Blender as copy 001 of the 608-Balls object, from which we copied the cage geometry.

If you have not been doing so at frequent intervals press **Ctrl-W** and save your work.

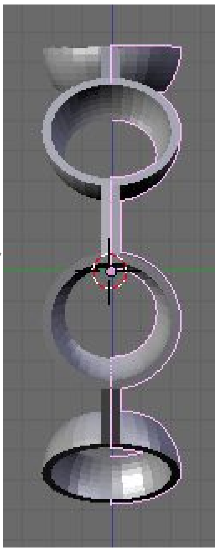
In Object Mode go to the side view **NumPad-3** and copy the cage **Shift-D** then press **Esc** so the position of the copy does not move.

We now need to Mirror this copy on the Y-axis. Ensure the cursor is on the Object Centre (centre of the bearing) and press **Ctrl-M** (Mirror)

This will bring up the Mirror Axis sub menu choose "Y Local".

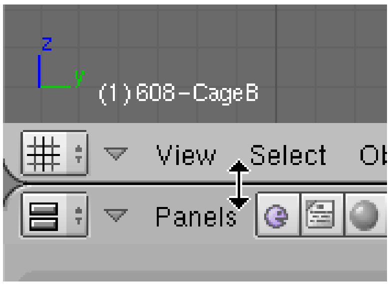
The copy will flip over to be a mirror image of OB:608-CageA with the name OB:608-CageA.001.

In the Links and Materials panel rename this object OB:608-CageB.

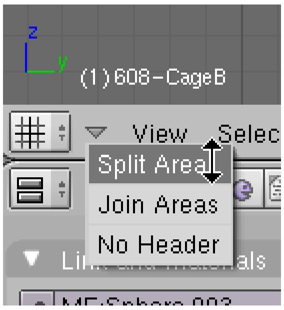


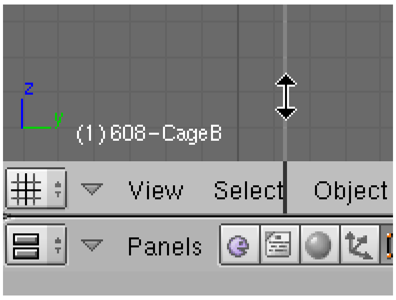
Our model now consists of four objects. To make selection easier blender has the ability to show an object layout in the form of a tree structure. This is seen in the Outliner window.

To enable this we first need to make room on our screen for a new window. Move the mouse over the join between the 3D view and Buttons Windows. The mouse pointer will change to a double arrow

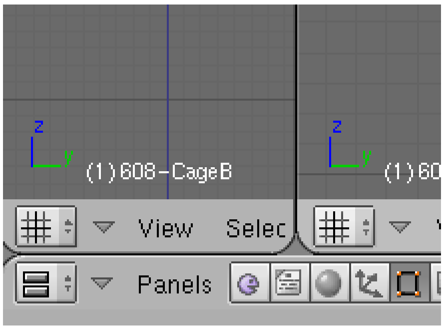


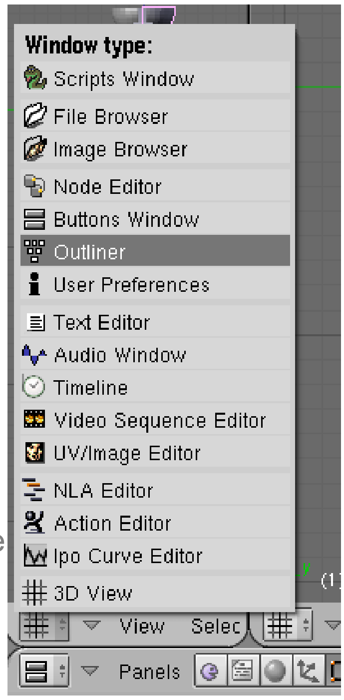
RMB click whilst the arrows are showing and a sub-menu will appear, **LMB** click on Split Area. A split line will follow the mouse pointer. Move the mouse over the 3D view.





LMB click and a new 3D view will be created.

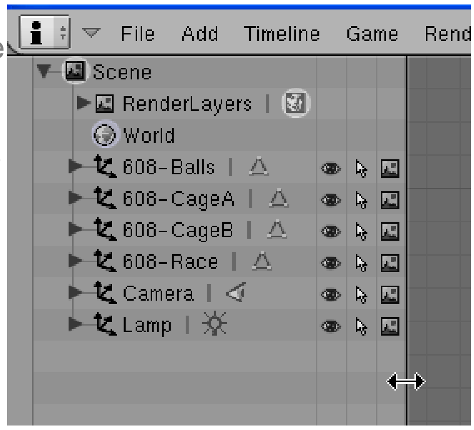




Click on the Window type button in the lower left corner of the new window, a Window type menu will appear choose Outliner.

The view will now show a list of all the objects that are in our scene (assembly and 3D space). Together with the default Lamp and Camera.

It may be necessary to increase the width of the Outliner window to see all the options. To do this move the mouse pointer over the join between the 3D view and Outliner, the pointer will change to a double arrow. Hold down the **LMB** and drag, the size of windows will change according to the mouse position.

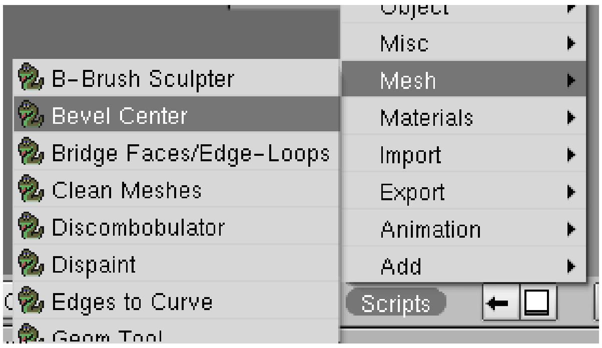


By clicking on the objects name in the Outliner, the object will become selected in the 3D view.

Clicking on the eye symbol will show or hide the object in the 3D view.

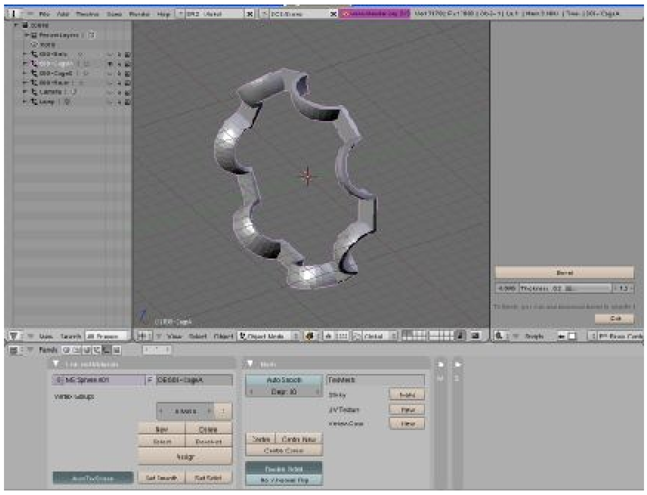
Clicking on the arrow will lock the object so it cant be accidentally edited.

The square camera icon stops the object being rendered to a bitmap image but still allows you to see it in the scene.



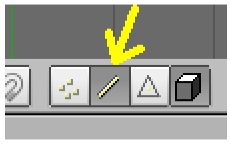
Now we have both sides to the bearing cage however there is still one operation that needs to be performed on OB:608-CageA. No mechanical parts have a perfectly square edge especially pressed parts like the bearing cage. So we need to add a chamfer to the outer edges of the object.

This process is greatly simplified by using one of the python scripts, so we need to open a scripts window. As above with the Outliner, split the 3D view but this time on the right hand side of the view. From the window type menu choose scripts window. In the scripts window **LMB** click on Scripts go to mesh and choose Bevel Centre. This will be used to add a chamfer to the chosen edges.

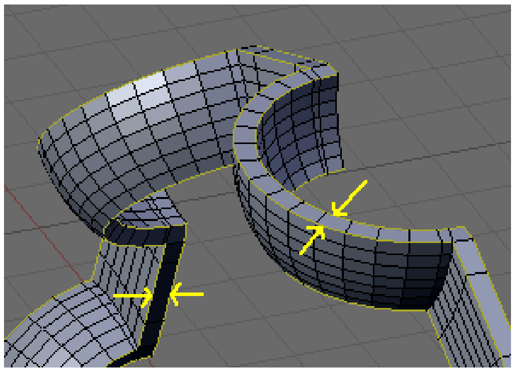


In the outliner window click on 608-CageA to select it and then click on the eye icon for the other objects to remove them from view.

Your screen will become quite cluttered and with the need to open more and larger windows the 3D view will become uncomfortably small, especially if you are using a small monitor. To make selecting and modeling easier you can force any of the windows to full screen by pressing **Ctrl-Down Arrow** with the mouse pointer over the window, giving a much better work area, pressing **Ctrl-Down Arrow** again will return the screen to the normal layout.



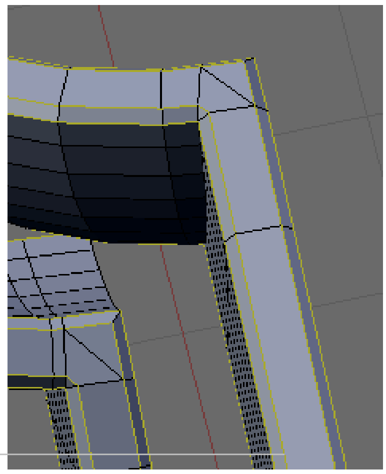
In Edit Mode zoom in on one of the cage spheres and set the selection to Edge Select.



It's now a matter of selecting all the edges on the outer and inner circumference.

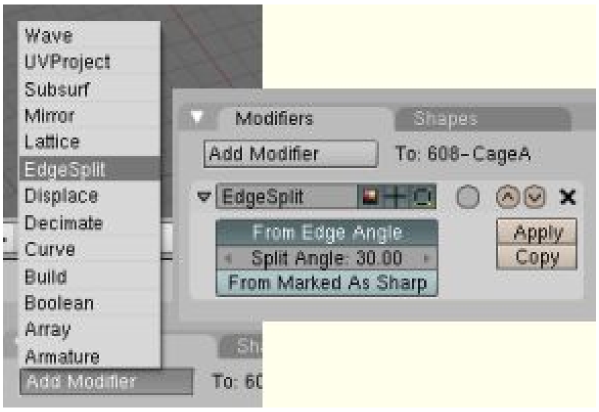
Shift-Alt-RMB select the edges indicated and work your way all around the circumference of the cage. Check you have four continuous loops selected. This check may be easier in wire mode **Z**.

In the Bevel Centre **Shift-LMB** over the thickness figure and change it to 0.05. This will give a 0.05mm chamfer.

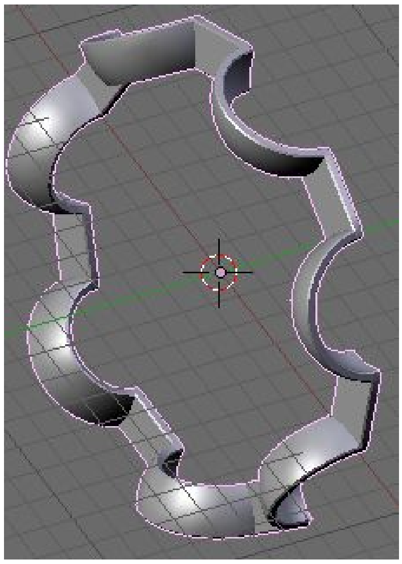


Press Bevel and after a few seconds a chamfer will be created on the selected edges.

To get a smooth appearance on our cage we will add an Edge Split modifier. In vertex Select, select all vertices **A** and in the Mesh Tools panel press Set Smooth.



In the Modifiers panel press Add Modifier, From the pop up menu choose Edge Split. In the Edge Split modifier "From Marked As Sharp" and "From Edge Angle" will already be selected. Leave Split Angle:30. Which will smooth the join between any faces with an angle of 30 degrees or less.

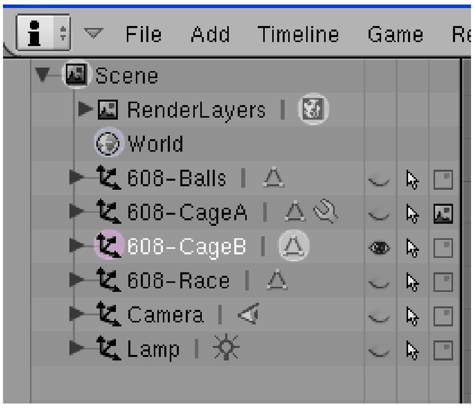


If black patches appear on the surface this is because the computer doesn't know what side of the face is outside. To correct this press **Ctrl-N** and recalculate normals outside.

OB:608-CageA is now complete.

Press **Ctrl-W** and save your work.

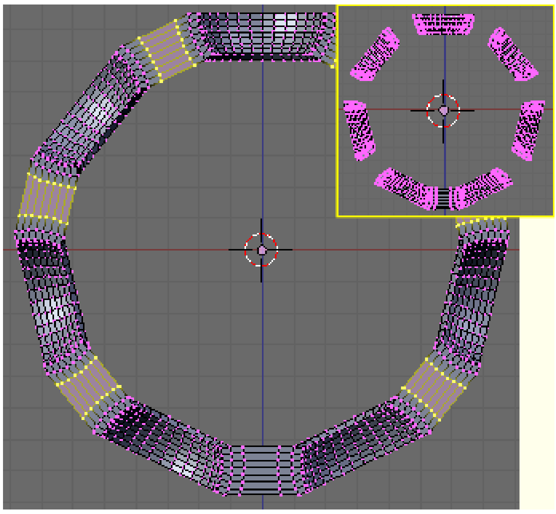
In part 5 we will add the clasp that joins the two half cages to OB:608-CageB.



With 608-CageA now complete its time to go back to Cage B which we copied and mirrored from cage A before the chamfers were added.

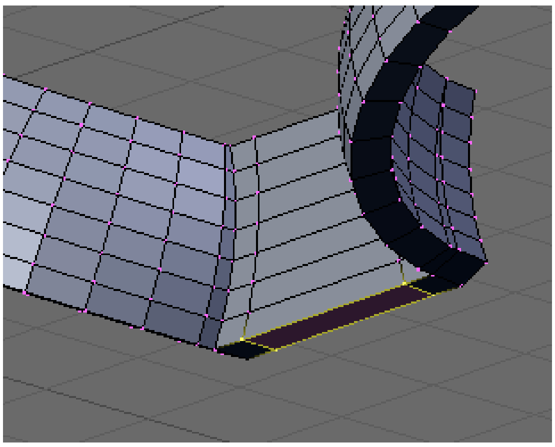
In the Outliner click on 608-CageB, select the Eye icon to bring it into view and close the eye icon of 608-CageA.

When we originally mirrored the cage from 608-CageA, we effectively applied a scale factor of -1 in the Y axis. Press **N** to open the Transform Properties window, You will see ScaleX:-1.000. To clear this back to ScaleX:1.000 we need to apply the scale to the object. To do this press **Ctrl-A** and accept "Apply Scale and Rotation". If you had simply changed the number in the Transform Properties window to 1 the cage would have flipped back to the other side of the bearing

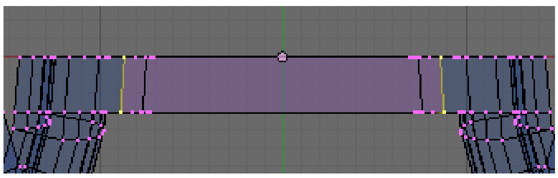


In front view select the vertices that make up the loops we cut in the bridging section between the ball cups. **Shift-Alt-RMB** but leave the vertices of the bottom bridging section deselected as these are parallel to the X axis and the easiest to modify.

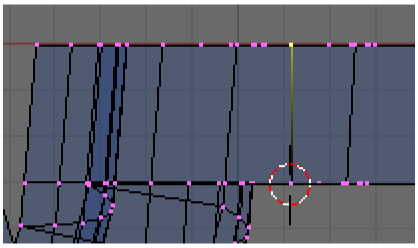
With the vertex loops selected on all but the bottom section, press **X** to delete them



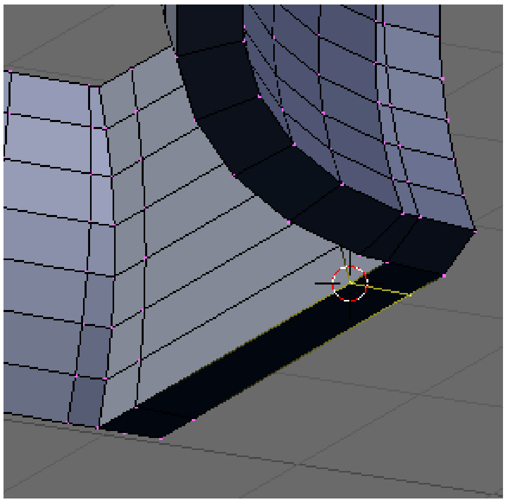
Zoom **SW**, pan **Shift-MMB** and rotate the view **MMB**, until you obtain a good viewing angle on the bottom face of the remaining bridging section. Select the central bottom face. (**Shift-RMB** the 4 vertices on the corner of the face.)



Switch to top view and go into wire view mode **Z**. you will see the selected edges are not square because they were cut from geometry originally created from the ball bearing's UVspheer, so we need to square up the edges.

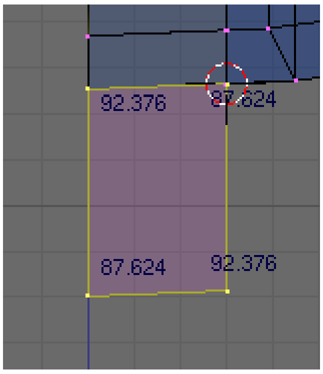


Select the face vertex on the outer surface of the cage and **Shift-S** snap Cursor/>Selection. Select the vertex on the opposite end of the edge and Scale **S** constrain **X** to a scale point of **0**. Repeat this on the other edge of the face.



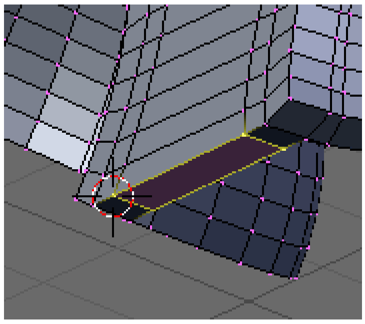
Select one of the edges that cross the bottom face. Go to side view and wire view mode. You will see that the edge is not aligned to the Y-axis, this is because of the same reasons the edge above are not square.

Extrude **E** (Only Edges from sub menu) a face from this edge constrained in the **Z**-axis. The length of the face is not important. We will use this face to see what angle the edge is at.



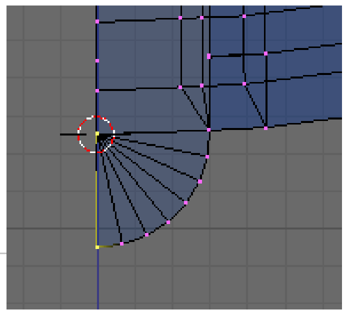
In the mesh tools 1 panel select edge angle and then select the four vertices of the face. The angle of each face corner will be displayed.

To form the clasp we need to spin the bottom face 92.376 degrees. Select only the bottom two vertices and delete them **X** as they were there just to obtain the required spin angle.



Select one vertex on the inside edge of the bottom face and snap **Shift-S** Cursor->Selection to position the cursor to the centre of the spin radius.

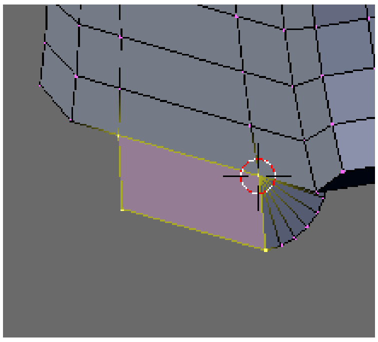
Shift-RMB Select the other vertices of the bottom face.



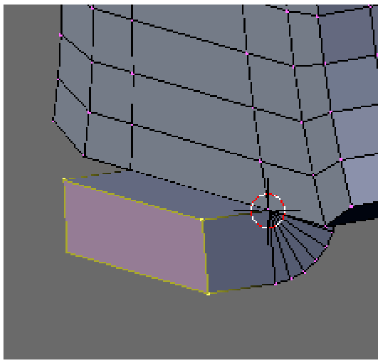
Go to side view **NumPad-3**.

In the Mesh Tools panel set Degr:92.376 and Step:7 and press Spin. Select all **A** and remove doubles **W** as we have also stacked 7 vertices on either end of the edge below the cursor.

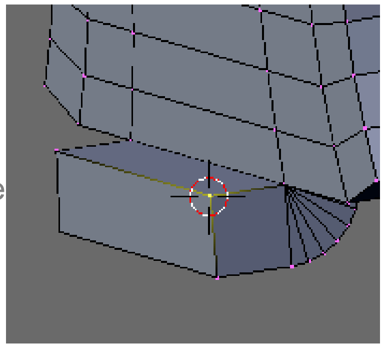
Re-select the newly spun face and Extrude **E** (Region from sub menu) and **0.3** for the distance. When you select region a new face will be extruded constrained to an axis perpendicular to the original face.

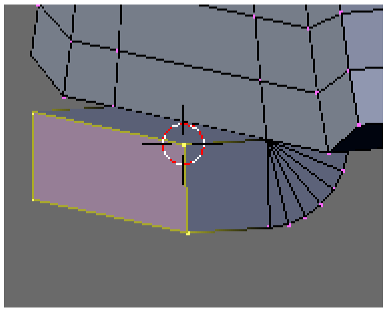


If the face extrudes in the wrong direction press grab **G** constrain to **Y** and distance **-0.6** (-0.3 to bring it back to the cursor and -0.3 for the correct position)



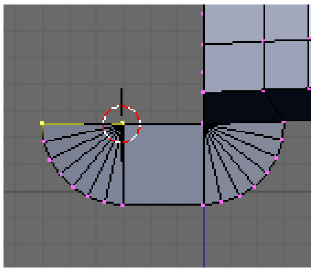
Select one vertex on the top edge of the new face and snap the Cursor to the vertex. This sets the centre for the next spin. Then select the remaining vertices of the face.





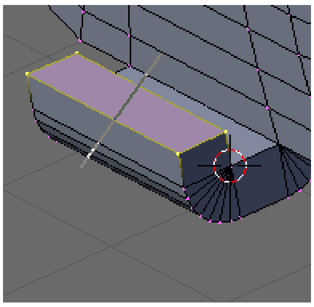
In the Mesh Tools panel set Degr:90 and leave Step:7. Go to side view and press Spin. The next section of the clasp will be formed.

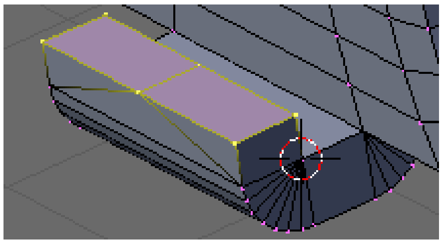
Select all **A** and remove doubles **W** to remove the vertices stacked under the cursor.



Reselect the newly created face and extrude (Region) 0.2mm

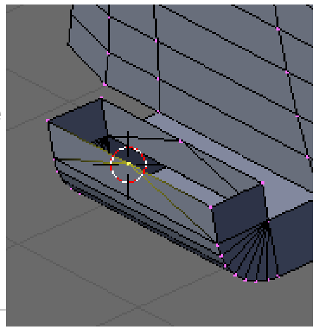
With the vertices of the face still selected cut a new edge across the centre of the face. **K** Knife (Midpoints). Two new vertices will be created.





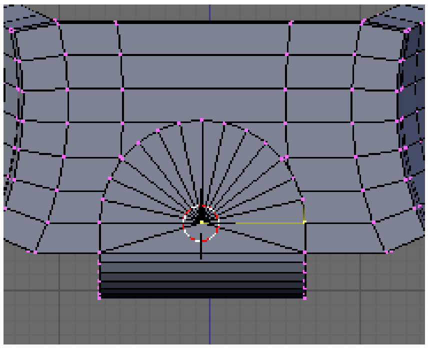
Select the two new vertices and delete **X** (Edges). The edge joining the two vertices and both faces either side will be deleted.

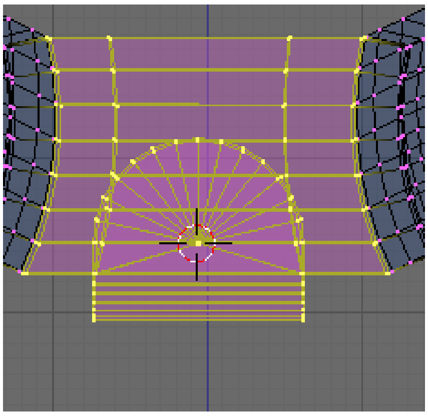
Select one middle vertex and snap the cursor to it.



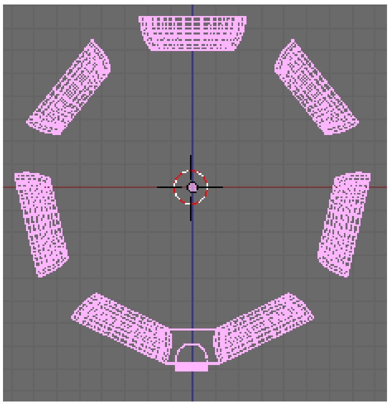
Select the two centre vertices and the two on the left edge. We will spin these in front view to form the front radius of the clasp.

In the Mesh Tools panel set Degr:180 and Spin:14, go to front view and then press Spin. As before select all and remove doubles.





Select the newly formed clasp and the four edge loops that make up the bridging section.



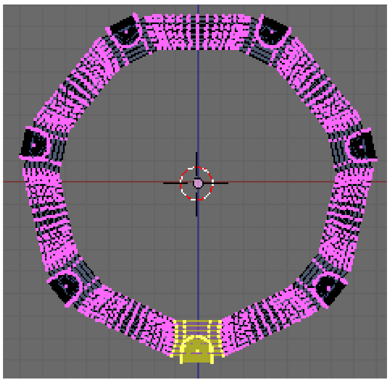
We are now going to Spin Dup the new bridging section with the clasp around the cage.

Tab into Object Mode and snap the cursor to the object centre.

Tab back into Edit Mode.

In the Mesh Tools panel set Degr:360 and Spin:7.

Press Spin Dup to copy the bridging section between the cage spheres.



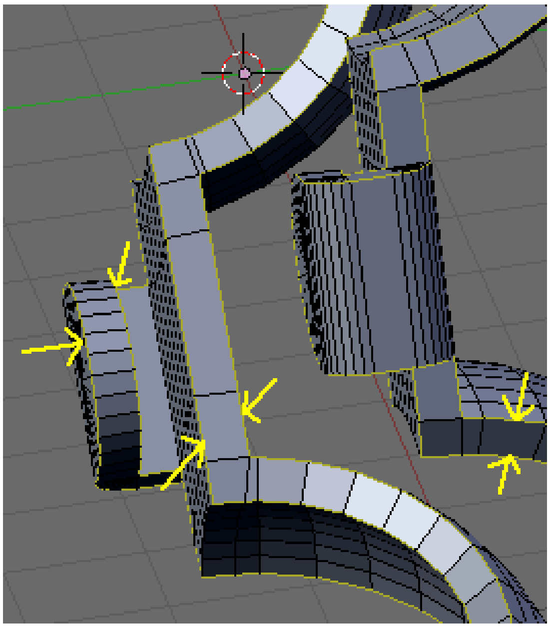
Select all and remove doubles.

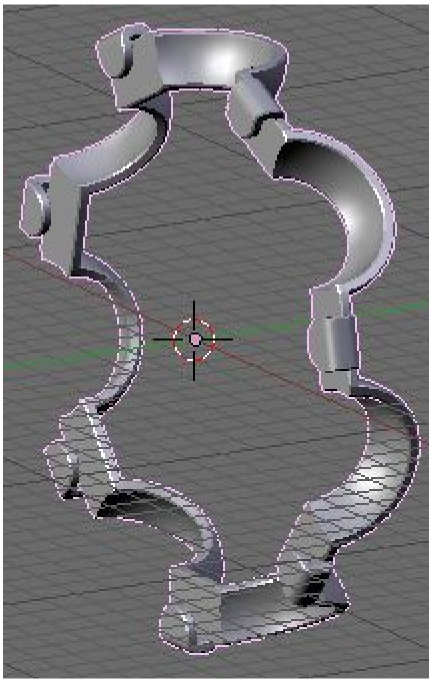
Its now time to add the fillet around the edges of the cage. This time the outer edge loops will also follow around the clasp.

Follow the details in Part 4 to add the Fillets but with Edge Select activated make sure you select continuous loops that also include the clasp.

Add the 0.05mm Fillets with the bevel Centre script.

Add the Edge Split Modifier also detailed in Part 4

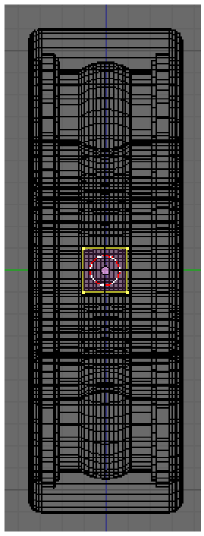




This completes OB:608-CageB

Press **Ctrl-W** and save your work.

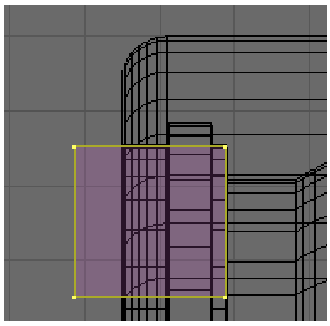
In the next section's we will add the dust shield and circlip to complete the detailed model of the 608 bearing



The dust shield will be formed in the same way as we made the bearing inner and outer race. We will create a section through the dust shield and spin this around the bearing centre to form the 3D component.

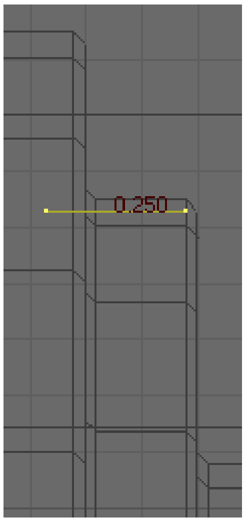
In the Outliner set the 608-Race to visible and hide all the other parts. In Object Mode snap the cursor to the 608-Race object to set the cursor in the centre of the bearing.

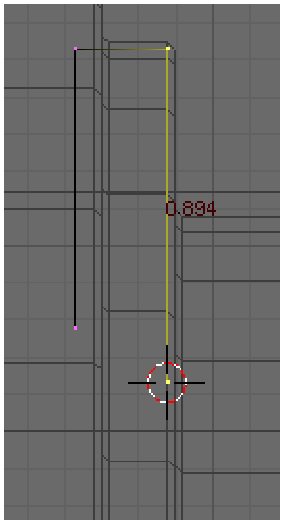
We will start this object with a plane, so press the **Space Bar** to open the Tools menu and Add>Mesh>Plane. The plane opens in Edit Mode.



Drag the four vertices of the plane and position them in the retaining grove of the outer race.

Select the bottom two vertices and delete them **X** as we will start the dust shield using only the top two vertices.

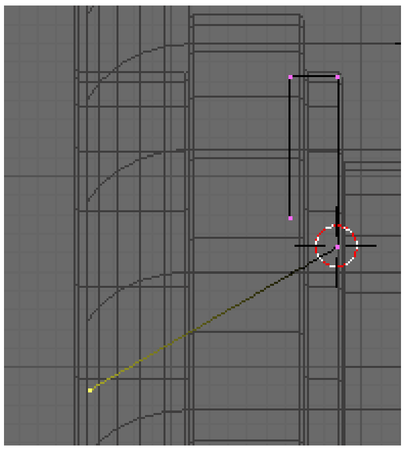




Grab **G** the end vertex and move it along the **Y-**axis **1.75**mm so the top edge measures 0.25mm, the thickness of the dust shield.

Extrude **E** (Only Vertices) the two end vertices in the **Z** axis **-0.75**.

Grab **G** the inside bottom vertex and move it in the **Z** axis a further **-0.144**mm to form an angle between the two vertices of 60 degrees from the vertical.

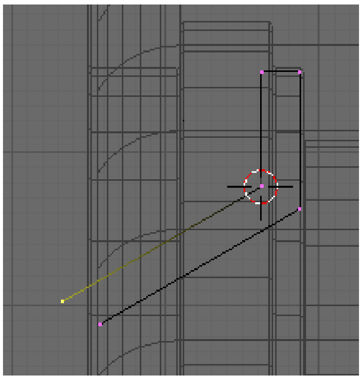


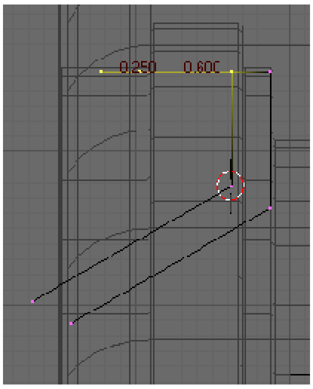
Set the cursor on the inside lower vertex and then extrude this -1.5mm in the Y axis.

Rotate **R** this edge **-30** degrees from the cursor.

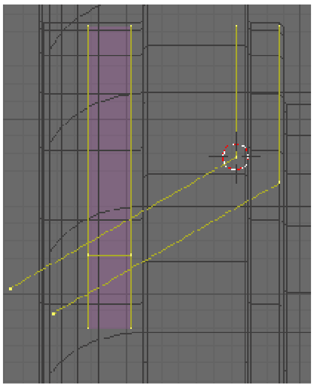
Repeat this for the outer edge.

The dust shield offsets 0.85mm so extrude two reference vertices from the top corner. -0.6 then -0.25 in the Y axis





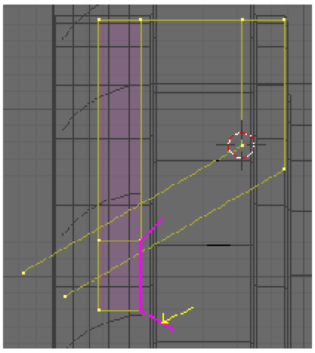
Extrude a face from these vertices constrained to the Z-axis and position the new vertices between the dust shield edges. Extrude another face along the Z-axis below the dust shield.



We will use the reference edges to accurately cut the angled dust shield edges to length.

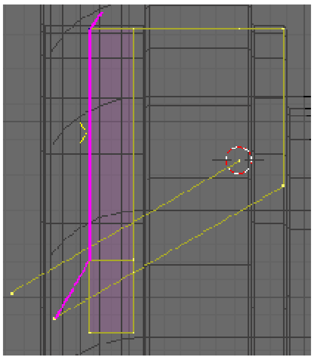
Select all vertices **A** and open the knife menu **K**, select Knife (Exact)

Click **LMB** below the lower right reference vertex, press **Ctrl** and move the knife towards the bottom left vertex the cut line will snap to the vertex click **LMB** to set the line then move to the vertex above **Ctrl-LMB** this vertex to snap the cut line, then press Enter to accept the cut.



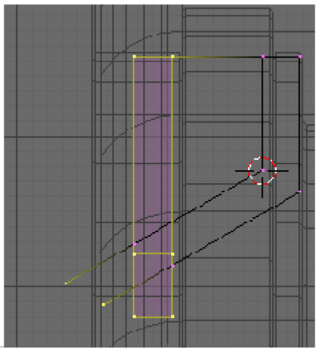
Repeat this on the outer edge but start the cut line on the top left vertex and cut to the vertex below.

We now have two new vertices setting the offset width of the dust shield.

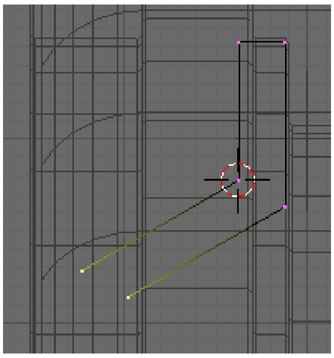


We no longer need the reference vertices or the end vertices of the dust shield edges.

Select these vertices and delete them **X**

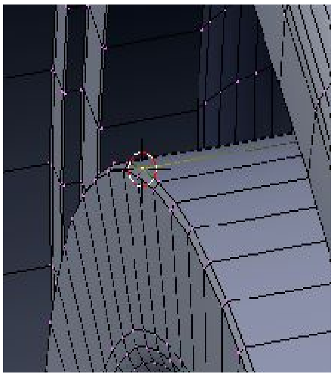


Select the two end vertices of the dust shield ready to extrude them.



Before we extrude them we need to set the cursor on the top of the inner bearing race. **Tab** into Object mode and select 608-Race. **Tab** back into Edit Mode for this object. Select a vertex from the top of the inner race **RMB** and snap the cursor to this, **Shift-S** Cursor->Selection.

Tab back into Object Mode, select the Plane object (dust shield) and **Tab** back into Edit Mode for this object.

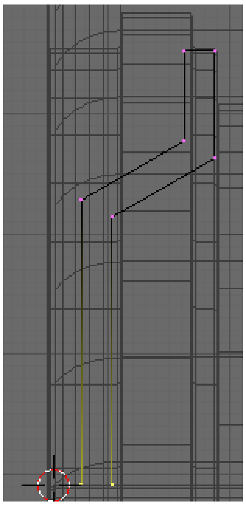


Extrude the two selected vertices towards the inner race constrained in the Z-axis.

We will now scale them onto the inner race.

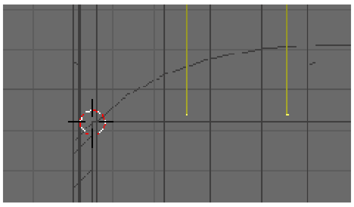
With the pivot point still set to 3D cursor press **S** for scale **Z** to constrain the movement to the Z-axis and **0** to scale the lines level to the cursor.

The vertices are now touching the inner race so we need to back them off a little to provide some clearance.



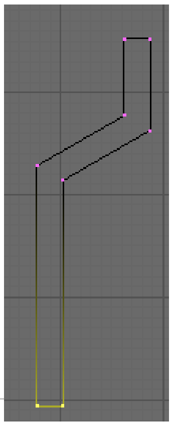
Move the vertices **G** (grab) **Z** constrain **0.02** for the clearance. The vertices will now be clear of the inner race.

To complete the basic shape of the dust shield press **F** to put an edge between the vertices.



We now have the basic cross section of the dust shield positioned accurately against the bearing race. As we no longer need to reference the bearing race press **Num-/** to go into local view for the dust shield.

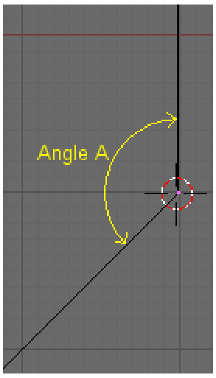
The last thing to do to the cross section is add some fillet radii to the offset corners.



Adding Fillets

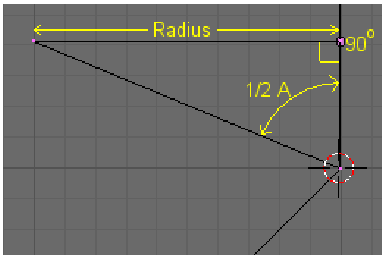
I will show two methods of accurately positioning the fillets, one using trigonometry and one using reference geometry that has no need for a calculator. For both methods you will need to know the angle between the edges, the fillet radius and have one edge aligned to a known axis.

Fillets - Trigonometry Method



First we need to know the angle between the edges we are going to fillet. If you haven't been planning the construction of your model and placing lines arbitrarily you can find the angle by forming a face from the three vertices and using the edge angle button in the Mesh Tools 1 panel.

Another requirement is for one of the edges to align with a known axis.



To work out the centre point of the fillet we simply construct a right angle triangle with half angle A and the radius. The hypotenuse is the distance to the centre point at an angle of half A

Therefore: Sin 1/2A = Radius/ Hypotenuse

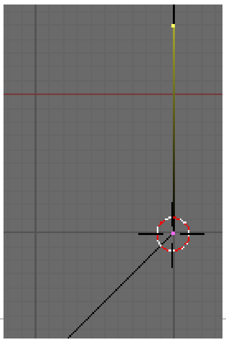
Hypotenuse = Radius/ (Sin (A /2))

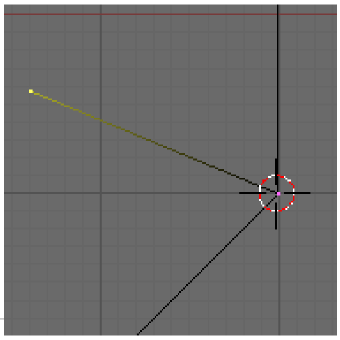
Once you have determined the hypotenuse simply extrude **E** this from the intersect along the known axis and rotate **R** it 1/2 angle A

Fillets - Reference Geometry Method

Extrude a vertex from the intersect 1.5 times the radius.

Rotate this vertex 1/2 angle A

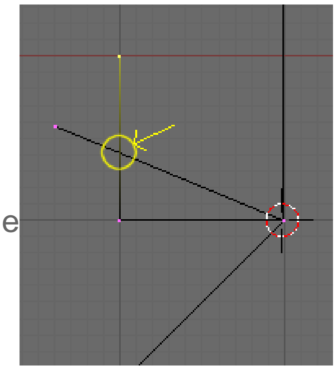


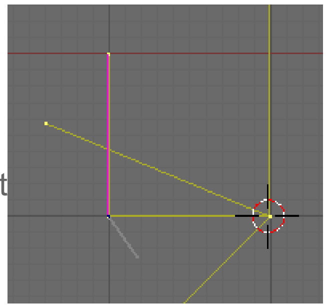


From the intersect extrude a vertex perpendicular to the edge on the known axis and the length of the fillet radius.

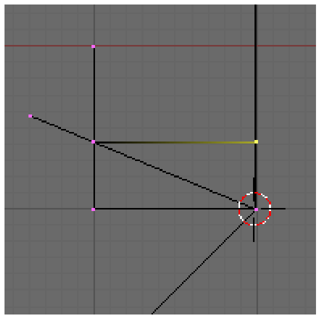
Extrude another vertices from this parallel to the edge on the known axis.

Where these two lines cross is the centre point for the fillet.

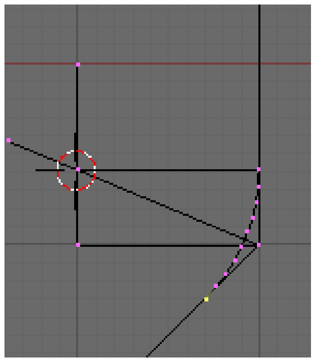




Using the knife tool **K** snap a cut line **Ctrl-LMB** between the two reference vertices parallel to the known axis line and cut a new vertex on the centre point of the fillet.

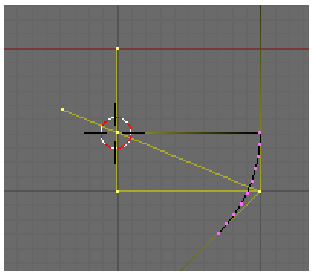


From the centre point extrude a vertex perpendicular to the edge on the known axis at the length of the fillet radius.

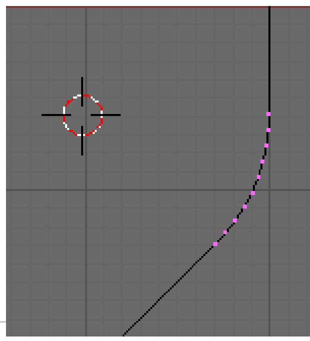


Set the cursor on the centre point and spin the vertex on the end of the radius edge through an angle of

180° - Angle A

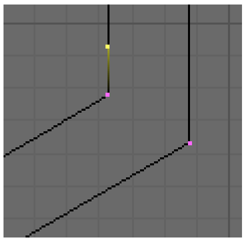


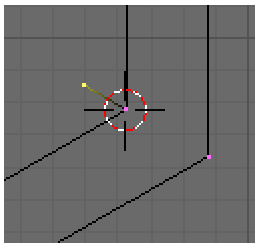
Delete the reference vertices.



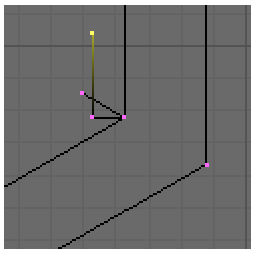
Re make the edges between the fillet and surrounding vertices.

Getting back to the dust shield we will use the reference geometry method to position the fillets with a small radius of 0.1mm and a large radius of 0.35mm. The angle between the edges is 120 degrees.

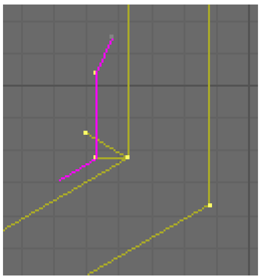


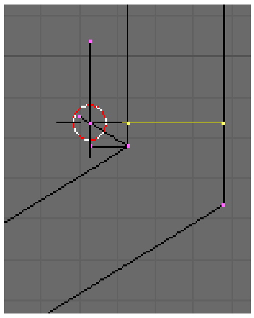


From the intersect on the inside of the angle extrude **E** a vertex along the **Z** axis **0.15**mm, then rotate **R** the vertex -60 degrees.



Again from the intersect extrude a vertex -0.1 in the Y axis (distance of radius) and then extrude this above the 60 degree edge.

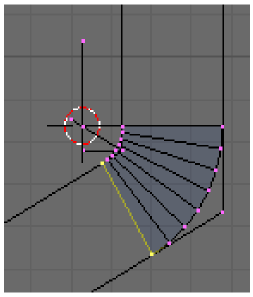




Select all **A** and then **K** Knife (Exact) a vertex on the 60 degree angled line snapping the cut

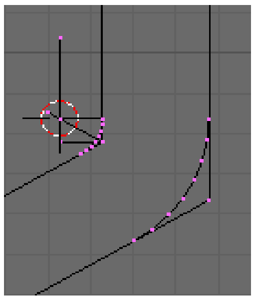
Ctrl-LMB to the edge set at the radius distance from the dust shield.

Select the new vertex which has been created on the fillet centre and snap the cursor to it.

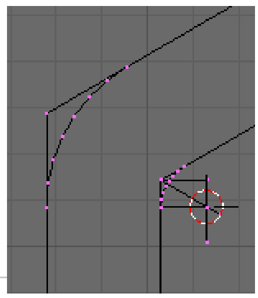


From the fillet centre extrude a vertex 0.1 on the Y axis for the front fillet then extrude this 0.25 on the Y axis for the back fillet.

In the Mesh Tools panel set Degr:60 and Step:7 and spin the two vertices.

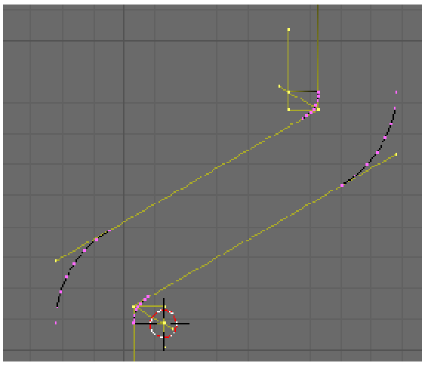


In edge select mode press **B** twice to bring up the selection painter reduce the size of the selection circle **MW** and select **LMB** the edges between the fillets. Delete **X** these edges.



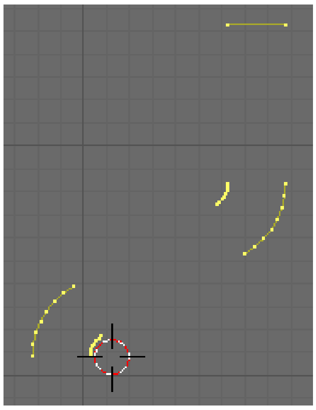
Repeat this procedure to produce the bottom fillet.

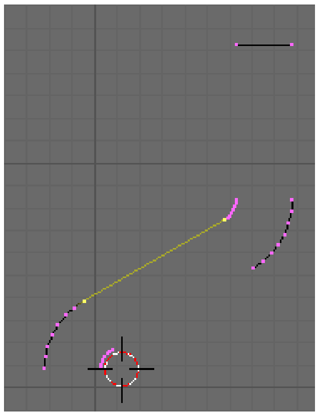
Back in Vertex Select mode, select the reference vertices along with those on the original angle intersects and delete them. We are now left with the fillet's and top and bottom edges of the dust shield.



Select a vertex either end of a missing edge and press **F** to insert a new edge.

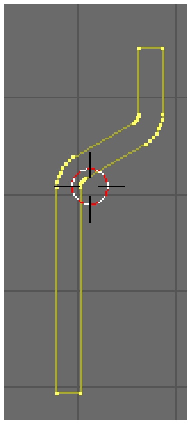
Repeat this for all the open sections.





We are now left with a completed cross section through the dust shield ready to spin into the 3D object, however as before the cursor is in the wrong position.

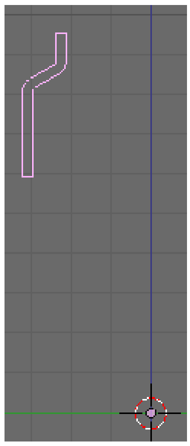
Select all **A** the vertices and **Tab** into Object Mode.



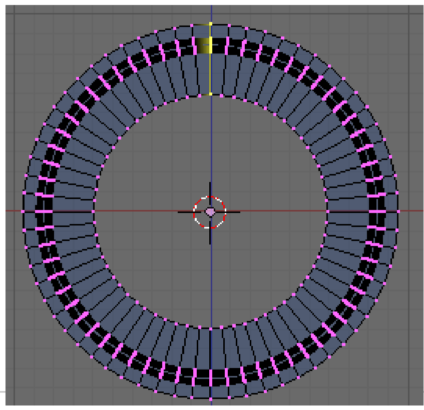
Snap the cursor onto the object centre. **Shift-S** Cursor->Selection.

Tab back into Edit Mode and go to front view **NumPad-1**.

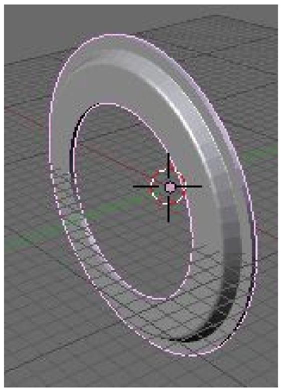
In the Mesh Tools panel set Degr:360 and Step:64 press spin to form the 3D object.



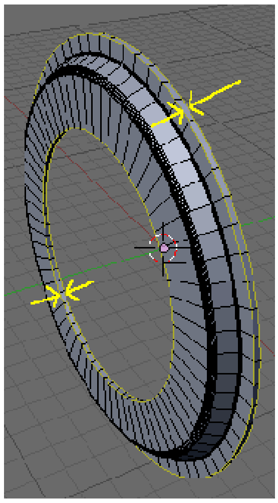
Select all vertices **A** and remove Doubles **W**.



The dust shield is now almost complete, but chamfers are required on the corners.

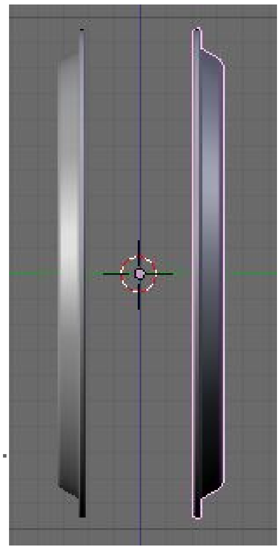


In edge select mode loop select the four edge loops indicated **Shift-Alt-RMB**



Using the Bevel Centre script detailed in Part-4, add a 0.05mm chamfer.

Finish the dust shield by adding an Edge Split modifier also detailed in Part-4.



A Dust shield will also be required on the other side of the bearing. Rather than repeating the modelling process we will duplicate this dust shield and Mirror it across the bearing centre.

Tab into Object Mode and go to the side view **NumPad-3**. Check the cursor is still on the object centre.

Press **Shift-D** to duplicate the object then **Esc** to leave the duplicate on top of the original.

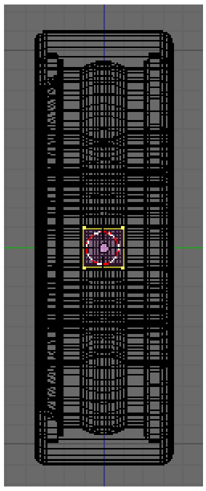
Press **Ctrl-M** to open the Mirror sub menu and select "X Local".

Both Dust shields have now been created so it is time to give them a meaningful name. Select Plane in the outliner and then in the Links and Materials panel change its name to OB:608-ShieldA. Repeat this for Plane.001 naming it OB:608-ShieldB.

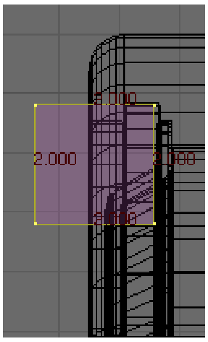
Press **Ctrl-W** and save your work.

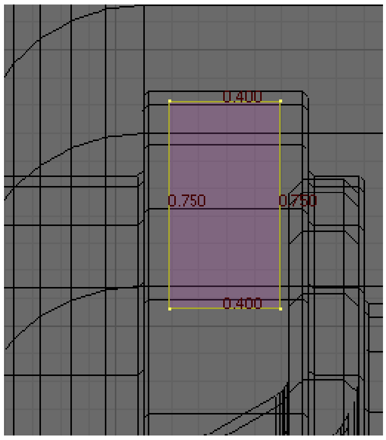
The final components for the bearing assembly are the circlips that retain the dust shields in place. These are covered in the next section.

The circlip is possibly the easiest of the parts to model. We will start by inserting a Plane object to form the circlip.



Whilst in Object Mode go to the side view **NumPad-3** and with the cursor on the bearing centre insert a Plane (**Space** to open the Toolbox then Add>Mesh>Plane).

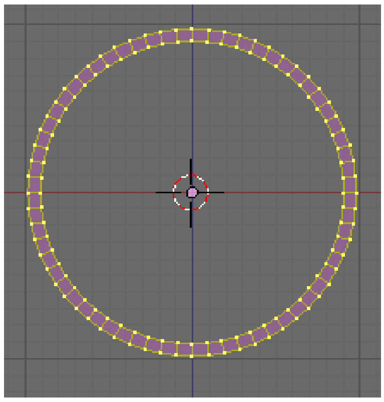




Move the vertices so the top right vertex is positioned in the circlip groove of the outer race.

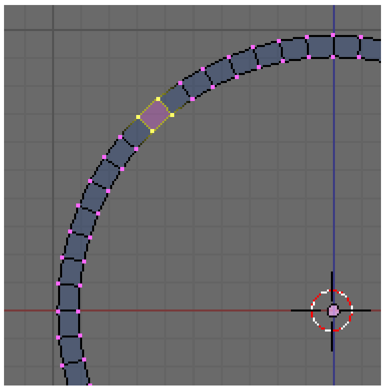
Select the left vertices, grab **G** and move them 1.6 in the Y axis so the width becomes 0.4mm.

Select the bottom vertices grab and move them 1.25 in the Z axis so the hight becomes 0.75.



Go into front view **NumPad-1** and spin the vertices around the bearing centre. In the Mesh Tools panel Set Degr:360 Step:64.

Press spin to form the 3D ring.

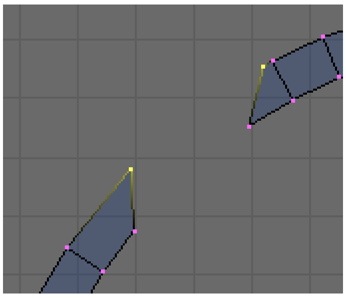


Select two loops of vertices through the ring and **X** delete them to form the opening in the circlip.

Make sure you have selected the vertices on the back edge as well as those on the front.

To allow the circlip to be prised out with a sharp tool the cut through the circlip is made at an angle.

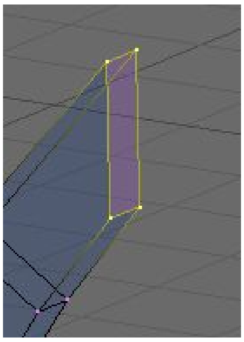
To form this select the four vertices on the outer edge of the break and rotate **R** them from the centre of the circlip.



Rotate your view and select the 4 vertices on one of the open ends.

Press **F** to insert a face.

Do the same on the other open end.

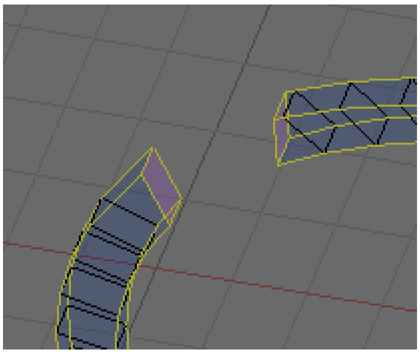


Go into edge select mode and loop select the four edge loops forming the inner and outer edge **Shift-Alt-RMB**.

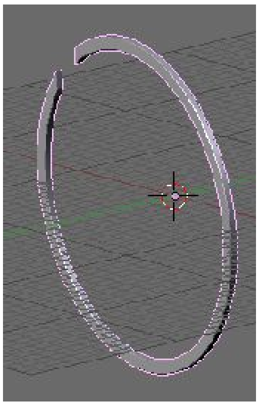
Select all the edges of the ends.

Using the bevel centre script detailed in part 4 add a 0.05mm fillet.

Select all the vertices **A** and in the Mesh Tools panel press "Set Smooth".



Finish the circlip by adding an Edge Split modifier with the default settings as detailed in part 4

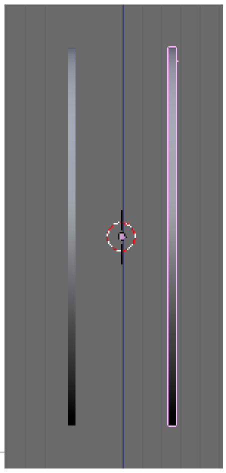


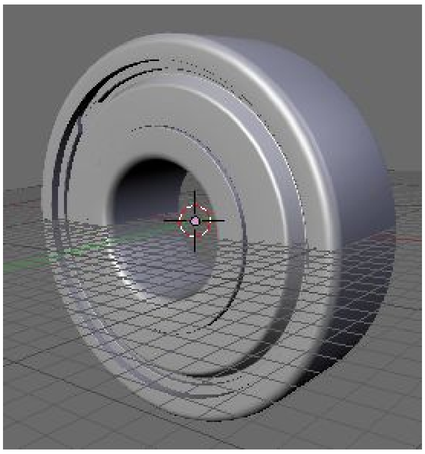
To finish off we will mirror this circlip onto the other side of the bearing.

In object Mode go into side view.

Copy the circlip **Shift-D** then **Esc** to leave it in the same position.

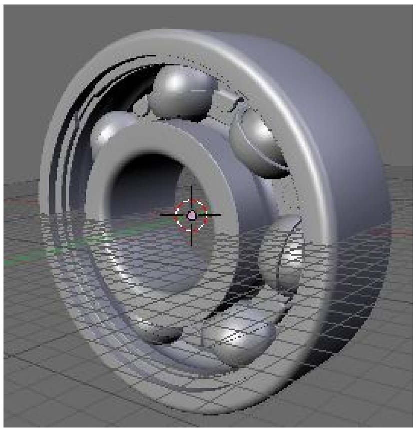
With the cursor still on the object centre **Ctrl-M** for mirror and select "X Local". The copied circlip will be mirrored onto the other side of the bearing.





In the outliner select Plane and then in the Links and Materials panel re name it OB:608-CirclipA. Select Plane.001 and rename it OB:608-CirclipB

That completes the modelling of the components for the detailed bearing. In the Outliner open the eye icon for all the parts to bring them into view. *(If the components don't appear you may still be in local view, try pressing* ***NumPad-/*** *to close local view)* Rotate the view to see your work.



The Dust Shields cover most of the components so you may want to hide one of the dust shields *(Outliner eye icon).*

Press **Ctrl-W** and save your work.

To recap: the commands and tools you have covered in this tutorial include.

Short Cut

7	Top	E	Extrude
1	Front	G	Move (grab)
3	Right Side	S	Scale
SW	Zoom In/Out (mouse **S**croll **W**heel)	Shift-S	Snap
MMB	Rotate View (**M**iddle **M**ouse **B**utton)	X - Y - Z	Constrain to Axes
Shift MMB	Pan View	Tab	Object/Edit Mode
Home	Centre View	Space	Toolbox
Z	Wire/Solid View	Ctrl-Z	Undo
LMB	Set Point (**L**eft **M**ouse **B**utton)	Edge Split	Surface (Modifier)
RMB	Select	Spin	Spin vertices around axis
Shift-RMB	Select Multiple Vertices	Spin Dup	Copy Vertices around axis
B	Box Select	Edge Split	Modifier
R	Rotate	W	Remove doubles (Specials menu)
K	Knife	Ctrl-N	Recalculate Normals Outside
Ctrl-E	Mark Sharp (Edge Specials menu)	Alt-RMB	Loop Select
B-B	Paint Selection	Shift-Alt-RMB	Multiple Loop Select
Ctrl-M	Mirror	Ctrl-D	Duplicate (copy)
Alt-S	Scale along normals		

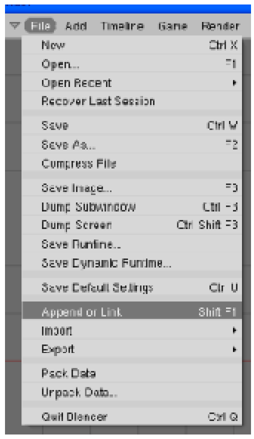
The completed bearing is ideal for producing visualizations or detailed drawings but with over 26,000 vertices it will require a lot of you computers resources if you have many of these in an assembly.

My CNC machines assembly model will require 60 bearings and at this level of detail that gives over 1.5 million vertices far more than my old PC can handle, so Part 8 will show how to retain the precision of the design but with substantially fewer vertices.

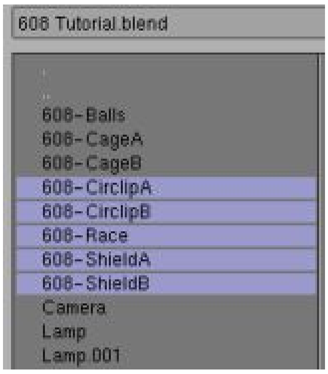
With the detailed model now complete its time to concentrate on the low vertices model that will have far less overhead on the computers resources when modelling large assemblies. We could start modelling from scratch repeating Part 1 but with fewer vertices on the fillets, however its a simple process to import (Append) the already created components into a new file and modify them. Open a new file and delete **X** the default cube.

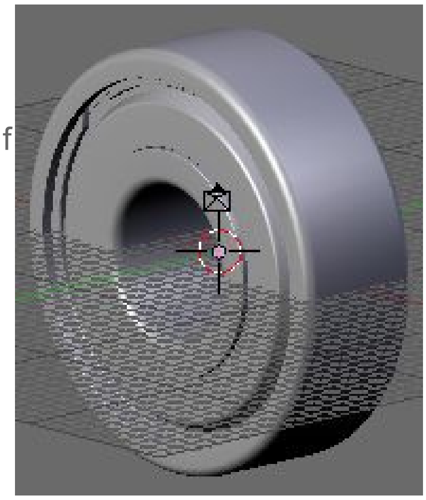
Turn off the transform manipulator (hand icon)

Click File in the top left hand corner and select "Append or Link"



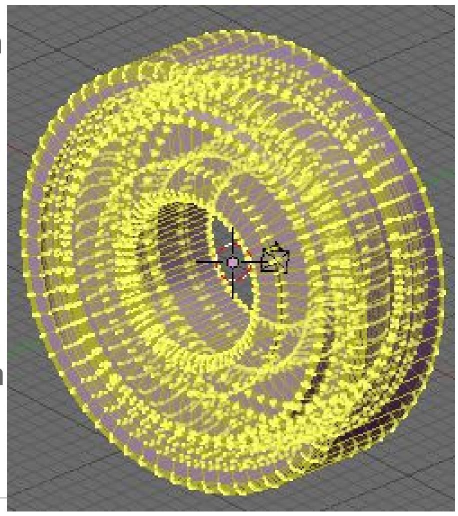
Navigate to the 608-Bearing.blend and from the options choose "Object". The components will now be listed. **RMB** on the components highlighted.





The five components will now be loaded in your file. If they are not visible open the Outliner and make sure the eye icon is open.

We need to join these components to make a single object.



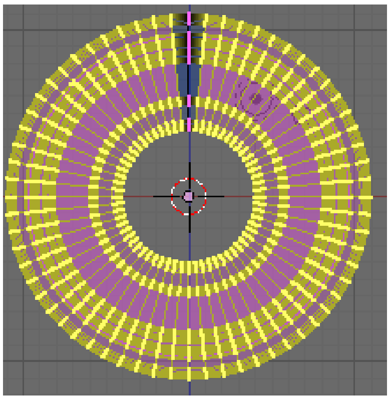
In the outliner select the five components and then with the mouse cursor over the 3D window press **Ctrl-J**. The components will be joined into a single mesh.

Tab into Edit Mode and press **A** to select all the vertices.

We only need a single cross section of vertices above the centre of the bearing. This cross section will be modified to reduce the number of vertices and then spun around the centre to form the bearing.

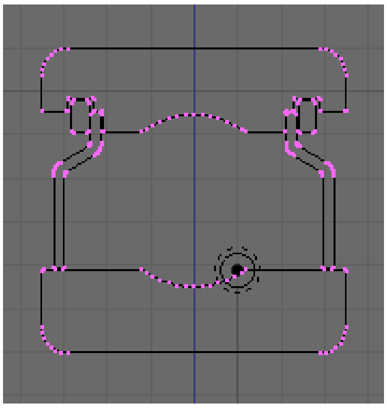
In front view press **B** twice to bring up paint select, reduce the size of the selection circle with the **SW** and pressing the **MMB** paint over the vertices directly above the centre.

The vertices will become deselected. Press **X** and delete all the remaining selected vertices.

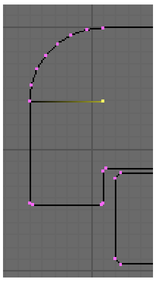


Were now left with a cross section through the bearing but still with far to many vertices and a lot of unnecessary internal detail.

We will start stripping out the detail by remaking the corner fillets with a smaller Step: value.



Select the lowest vertex on the top left corner fillet and extrude it 0.6mm on the Y-axis. This will give us the fillet centre point.

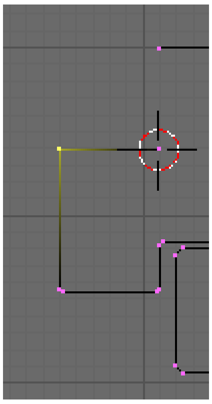


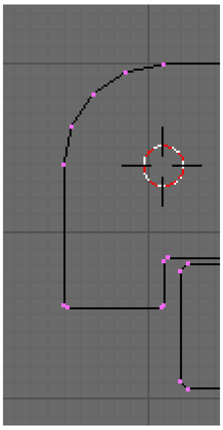
Snap **Ctrl-S**, Cursor->Selection onto the fillet centre. select the existing internal fillet vertices and delete them.

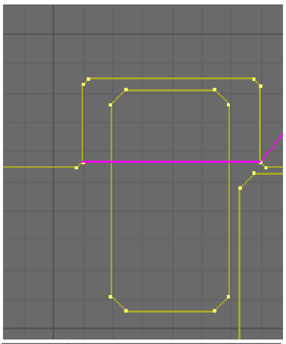
Select the original lowest fillet vertex and in the Mesh Tools panel set Degr:90 and Step:4.

Press Spin to create the fillet, this time with three fewer vertices. Delete **X** the vertex on the fillet centre.

Repeat this on the bottom left fillet.



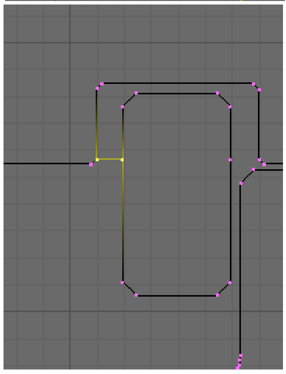




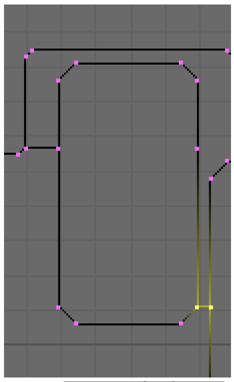
We now need to create a continuous external profile of the bearing, combining all the outer vertices of the loose parts.

Cut two new vertices through the left circlip snapping the line to the edge of the circlip groove's chamfer.

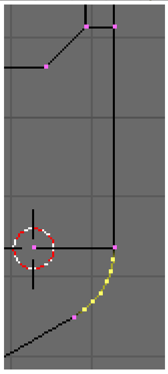
K Knife Exact, snap the cut line **Ctrl-LMB** to the circlip groove chamfer's.



Add an edge between the groove and the circlip **F**.



Repeat this and cut a new vertex on the dust shield with the snap line cut from the lower right chamfer of the circlip

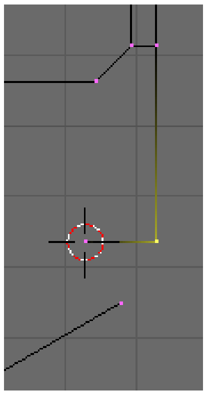


The offset fillet's of the dust shield still have more vertices than are needed.

From the top vertex of the top fillet extrude an edge -0.1 in the Y axis.

Snap the cursor to this new vertex which is on the fillet centre.

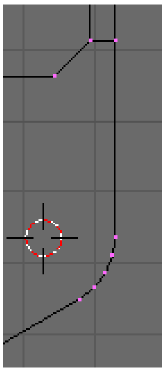
Select the internal vertices of the fillet and delete them.



Select the top vertex from the original fillet and spin this to form the new fillet.

In the Mesh Tools panel set Degr:60 Step:4 and press Spin.

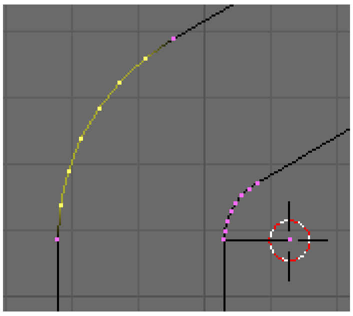
A new fillet has been created with three fewer vertices.



Move to the lower dust shield fillet and repeat the above process.

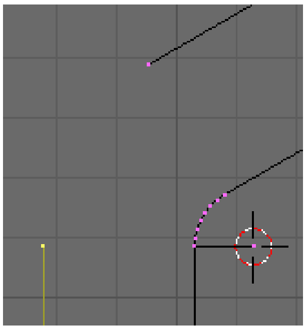
This time extrude the bottom vertex of the inner fillet 0.1mm on the Y axis to set the centre point. Snap the cursor to this.

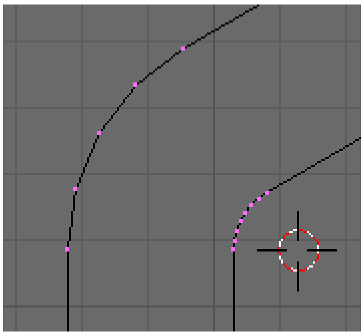
Select the inner vertices of the large outer fillet and delete them.



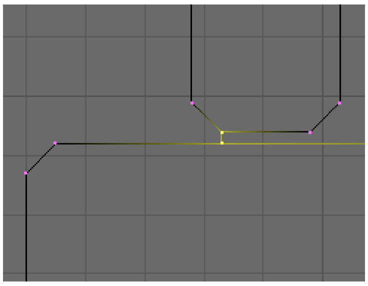
Select the bottom outer vertex of the original fillet and spin this Degr:60 Step:4

The vertices of the lower dust shield fillet have been reduced. Delete the fillet centre vertex.



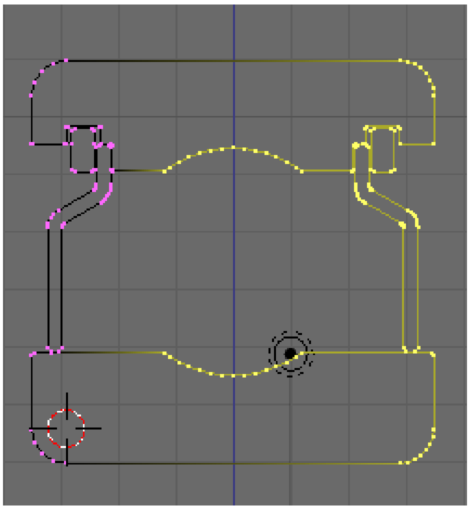


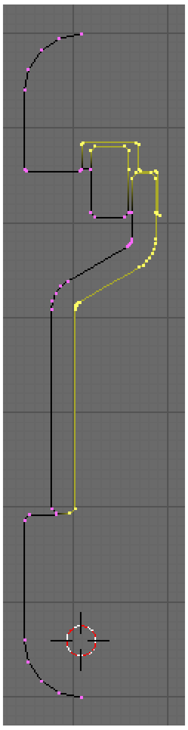
Cut a new vertex on the inner race from the dust shield bottom fillet. **K** Knife Exact, **Ctrl-LMB** to snap the cut to the chamfer, **MMB** to constrain to the vertical



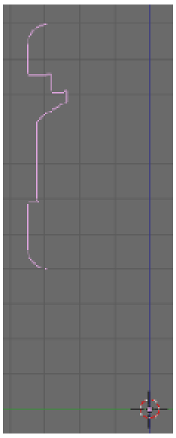
We now have a continuous outer edge of vertices down the left hand side of the cross section, rather than repeating this on the right hand side we can delete all the other vertices and mirror this line of vertices onto the right hand side.

Box select **B** all the vertices on the right hand side of the cross section including the bearing groves. Delete these **X**.

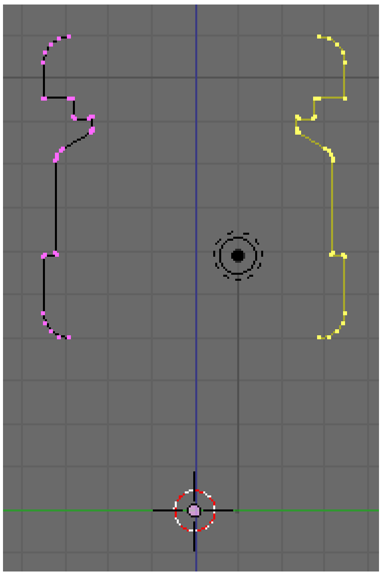




Paint Select **B-B** the remaining inner vertices and delete these.



Tab into Object Mode and snap the cursor to the object centre. **Shift-s** Cursor->Selection.

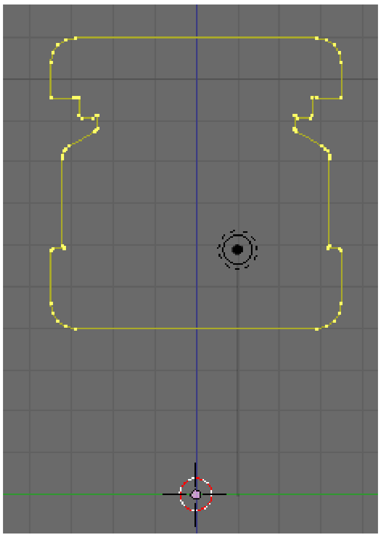


The cursor is now set on the bearing centre so we can mirror the left hand profile onto the right hand side of the bearing.

With the pivot point set to "3D Cursor" **Tab** into Edit Mode and select all vertices **A**.

Duplicate (copy) the vertices **Shift-D** then **Esc** to leave the copy over the top of the original.

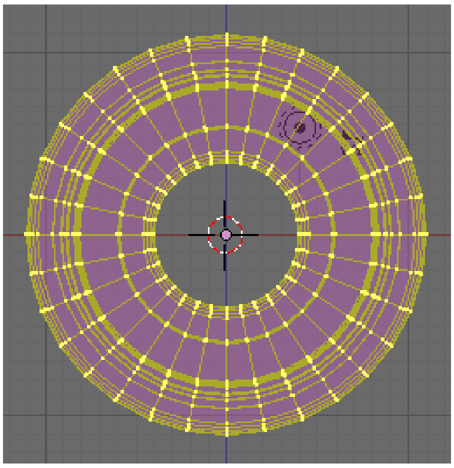
Press **Ctrl-M** to open the Mirror menu and choose "X Local". The copy will now be mirrored to the other side of the bearing.



Re-make the top and bottom edge by selecting a vertex either side of the opening and pressing **F**.

Select all **A** and remove doubles **W** to merge any doubled up vertices.

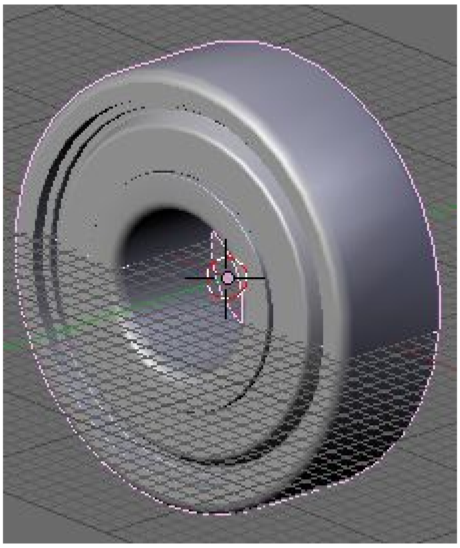
Go into front view **NumPad 1**.



In the Mesh Tools panel set Degr:360 and Step:32. Press Spin to form the 3D Bearing.

Select all **A**, remove doubles **W** and in the Link and Materials panel "Set Smooth".

As the bearing was created from the original components, an Edge Split modifier will still be activated on this object.



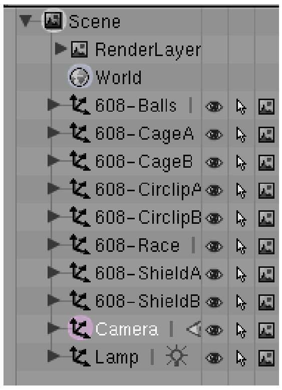
In the Link and Materials panel rename the object OB:608-BearingSmall.

Save the .blend file as 608-BearingSmall.

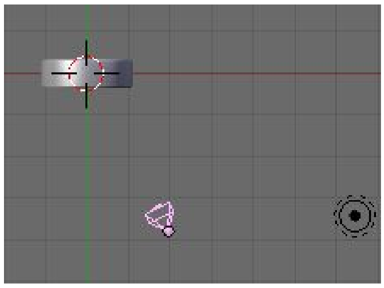
This version of the bearing has 2240 vertices, far fewer than the 26,000+ vertices of the detailed bearing. With 60 of these bearings in the CNC assembly it will still only require the computer overheads for 134400 vertices.

This completes the modelling of both versions of the bearing. In the next part we will look at adding basic materials to the bearing and rendering a 3D view and an exploded view of the bearing.

At the introduction to this tutorial I said I would not cover materials, textures or many of the other vast array of features available within Blender. However to use your model for visualisation or design drawing purposes you do need to know a little about the process of applying materials and rendering images to 2D bitmaps.

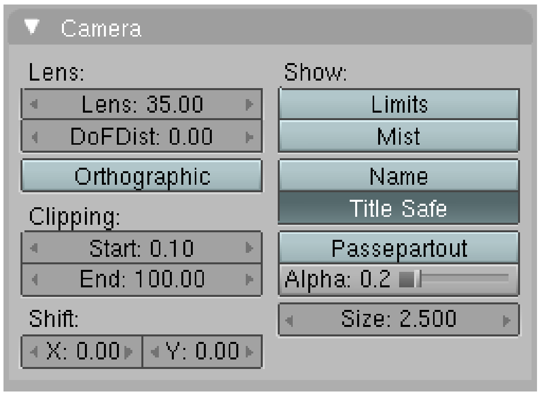


We will use the detailed model for this section so open the 608-Bearing.blend file. When Blender opens it automatically inserts a Camera and Lamp object into your scene (3D workspace), in the Outliner select the Camera object



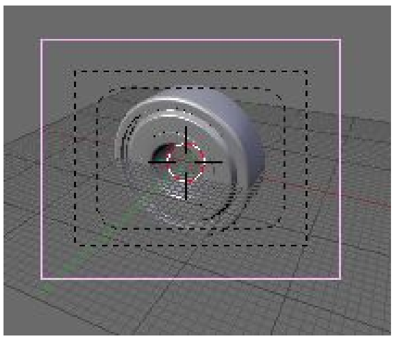
In top view move the camera **G** and position it to the front and right of the bearing.

Rotate it **R** to point at the Bearing, also check it points at the bearing in side view.



In the Editing Buttons window the Camera panel gives options for the camera.

The default lens is 35mm, to wide an angle for a decent image so change this to 55mm which will give a less distorted view. For a full description of the camera controls see the Blender Wiki.

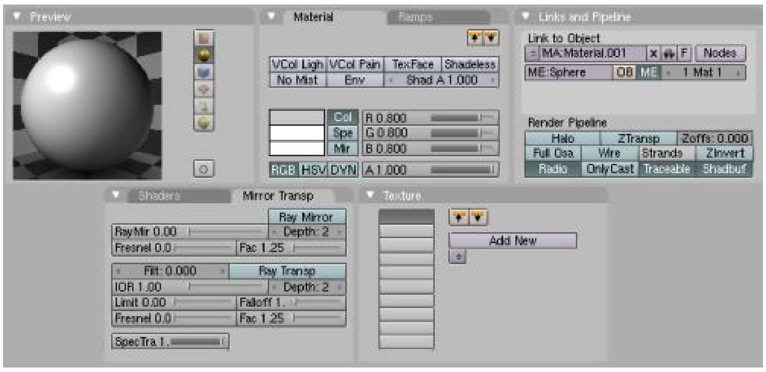


With the mouse pointer over the 3D window press **NumPad 0** which will open the camera view. Select the outer rectangle of the camera **RMB** and move it **G** so it is centred on the bearing. If the bearing doesn't fit in the camera view signified by the dotted rectangle truck the camera along its view axis **G-MMB** and moving the mouse.

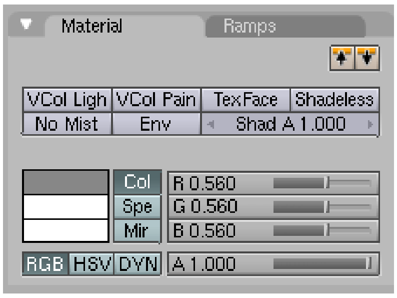
When the bearing is positioned in the camera's view select the bearing, then select the Shading button and the materials sub context button.

This will open the Links and Pipeline panel, click on add new to open a new material.

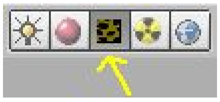
A range of material panels will become available to you.



In the Material tab change the R, G, B sliders to .560 to give a darker grey.

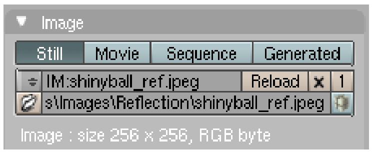


Click the texture sub context and in the Texture panel click “Add New”. Select "Image" from the pop-up list

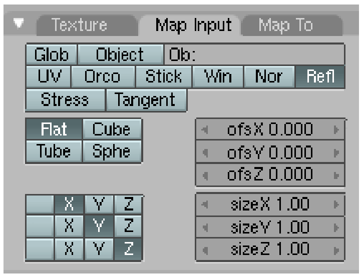


n the Image panel load the shinyball_ref.jpg image.

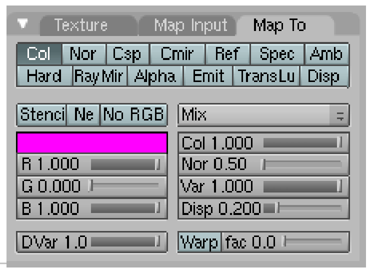
This can be downloaded from the Blender Texture Disk. A link to the Texture Disk is available on the Blender Web Site, on the resources page.



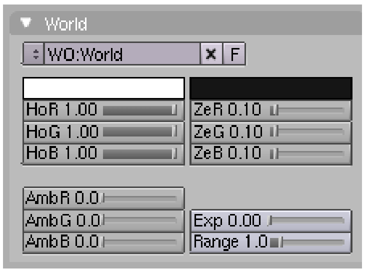
Go back into the material sub context buttons and in the “Map Input” tab and click Refl which will make the image affect the reflection vectors (See Blender Wiki).



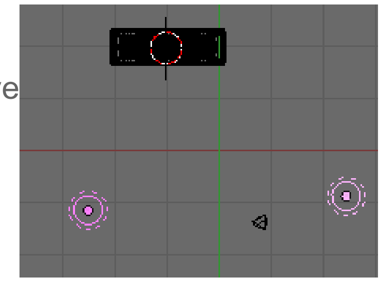
In the “Map To” tab leave the default settings.



Currently the 3D space has a dark blue background and we need to change this to white. In the World sub context, World panel change HoR, HoG and HoB to 1.00.

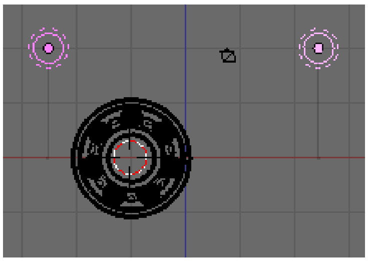


In top view **NumPad 7** select the Lamp **RMB** and move **G** it to the left of the camera.

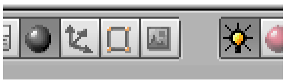


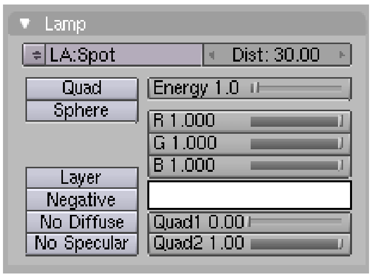
Copy the Lamp **Shift-D** and move the copy to the right of the camera.

In front view, select both lamps **Shift-RMB** and move them **G** above the bearing.



Lamp Buttons

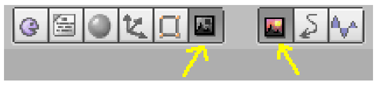


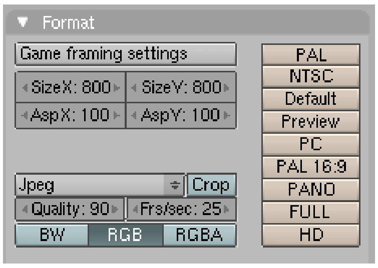


The Lamp panel gives the settings for Energy, distance, colour etc.

The default settings should be OK for this render.

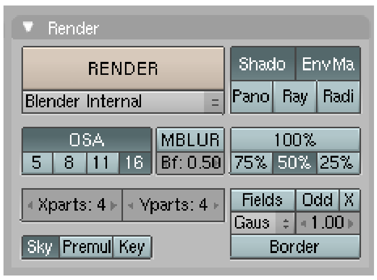
In the context buttons, click on the scene and sub context Render button.





In the Format Panel change the Size x and Size Y to 800 pixels and change the image format from Jpeg to PNG.

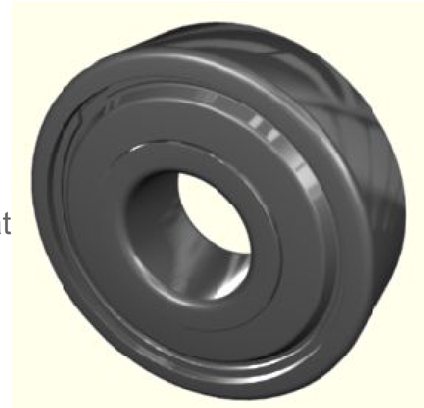
In the Render panel de-select "Ray", as we don't need to use Ray Tracing.



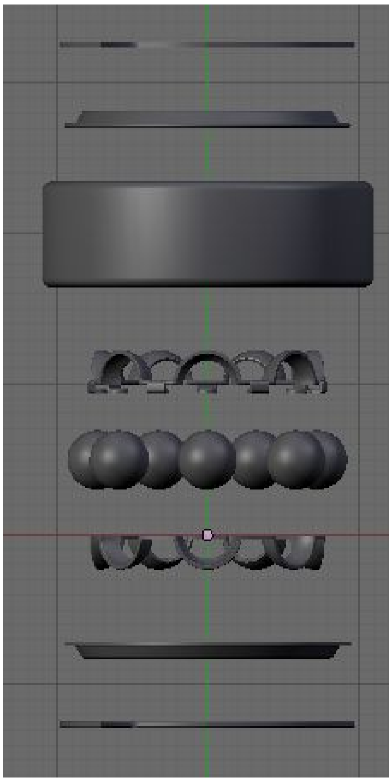
Set "OSA" to 16, so we get a good smooth edge to the render.

Press the Render button, a new window will open and an image of the bearing will be created.

To save the image go to File>Save Image or Press **F3**. The active window will change to a file window allowing you to save the image as a .png file.



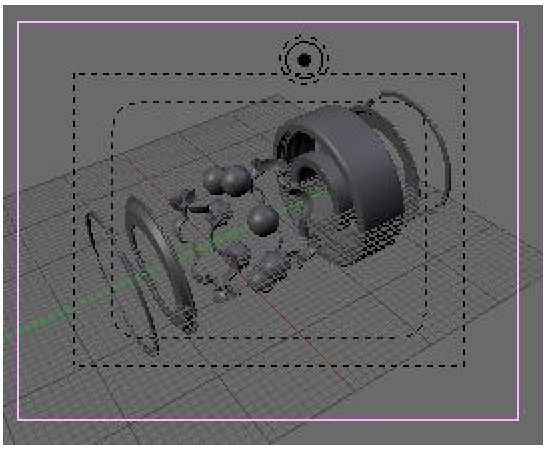
This is a pretty basic grey colour material and with a little time and experimentation with the material controls, a much more convincing material could be obtained. Read the blender documentation and look at examples of materials posted by other users to gain more experience in creating realistic materials.



As most of the parts we have modelled are hidden within the dust shields it would improve a drawing layout if we included an exploded view.

This can be created by simply moving each of the components along the Y axis.

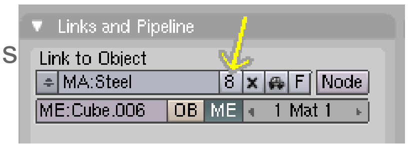
Go into top view **NumPad 7** and select the back circlip move it constrained to the Y axis away from the bearing. Repeat this for all the other components spreading them in order along the axis. They can easily be reassembled by snapping the cursor to the bearing race and then snapping the other components to the cursor.



Reposition the camera to get all the components in the view.

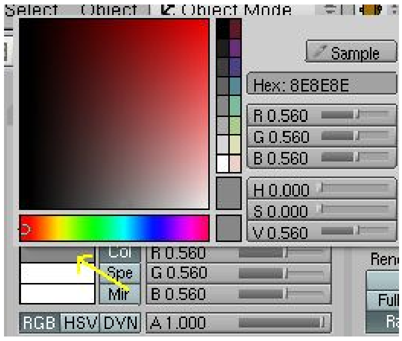
With all the parts being the same material it is a little confusing and difficult to separate the parts where they overlap. To overcome this we can change the material of the bearing cage to a brass coloured material.

Select 608-CageA .



In the Links and Pipeline panel after the material name is the number of objects using the material.

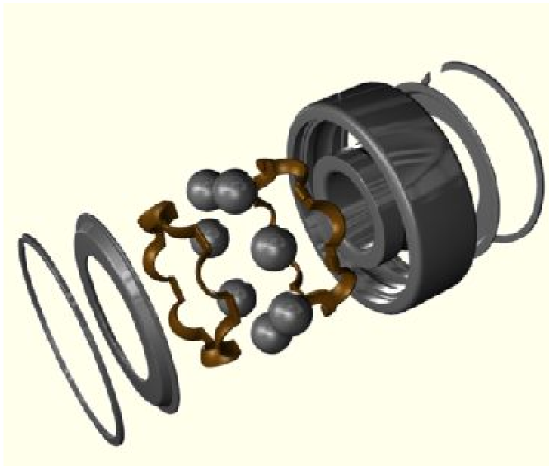
Click on the number and accept "Single User". This will stop the following material changes affecting any of the other objects. Rename this material Bronze.



To change the colour of the cage click on the colour square in the Materials tab. This will open the colour picker. Choose a bronze colour.

In the "Mirror Trans" tab de-select Ray Mirror and in the Texture tab click on Clear to remove the reflection image.

To add this material to the other half of the Cage, select 608-CageB and in the links and Pipeline tab click on MA:Steel. Select Brass from the list.



To output the picture of the exploded view select the Render Buttons and in the Render panel press the Render Button.

As before a window will open and the Exploded View will be produced.

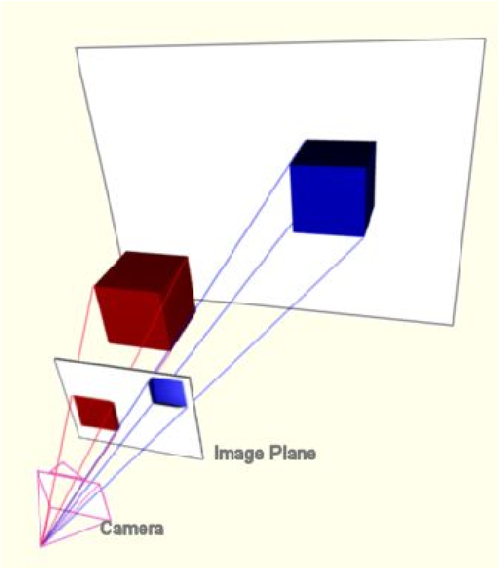
Press **F3** and save the image.

With the two images created press **Ctrl-W** and save your .blend file.

In the next section we will create a page template for a scaled line drawing of the bearing.

Camera

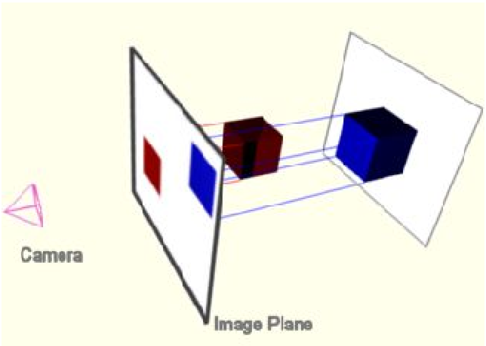
Before we go into the process of laying out the drawing view's, an understanding of Blenders camera is needed.



Perspective Projection

The two images we have created in Part 9 use the camera in perspective projection mode and gives similar results, as you would get if an actual bearing had been photographed.

The size and shape of the image on the image plane is a product of the focal length of the camera, distance of the object from the camera and the object size. This type of camera will never give us the flat-scaled 2D drawing required.



Orthographic Projection

Blender includes an orthographic mode for the camera, which takes a parallel slice, the size of the image-plane through the 3D workspace. The size of the image plane can be set to suit the overall size of the drawing you need to output.

Printer

The next thing we need to consider is the printer. For engineering purposes we are most likely working to a scale of 1 Blender unit equals 1 millimetre and the output from the camera is likely to be in 96 DPI (dots per inch) The usual output from a printer will be 300 DPI. So how do we get a drawing to scale out accurately onto a printed page?

Setting up the Scale

The way I find easiest is to set the camera scale at a multiple of 25.4 and set the size X and Size Y in the Format panel of the Render Buttons to an equivalent multiple but this time of 300. So if you wanted to have a 1:1 scaled image fit onto an A4 page of 11" by 8" you would need to set the camera scale to 25.4 x 11 = 279.4, the Format panel Size X: to 8 x 300 = 2400 and Size Y: to 11 x 300 = 3300. There is one further requirement as the image is set to print at 96 DPI not 300 DPI. This requires the use of an image-editing program such as the Gimp or Photo Shop, to change the output size of the image to 300DPI.

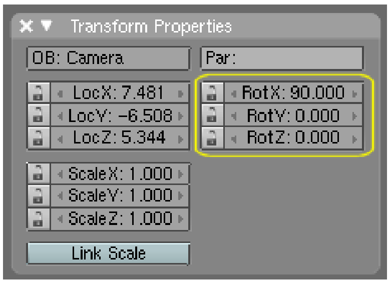
If you want to set your page up to print at an exact size and at a scale other than 1:1 the correct Camera scale factor and output resolution become a little more difficult to set up. The easy solution is to scale your model once you have set the camera to suit the page template.

Page Template

Save anything you currently have open **Ctrl W** and open a new Blender file **Ctrl X**. We will start by making a page template to suit an 8 x 11inch page, in front view add a Plane **SpaceBar** Add>Mesh>Plane, select and grab the top two vertices moving them 277.4mm *(25.4 X 11 inches - 2 the original Plane size)* in the Z axis. This sets the height of the page. Grab the two right-hand vertices and move them 201.2mm *(25.4 X 8 inches - 2 the original Plane size)* in the X axis, to set the width of the page. Select all vertices and delete **X** Only Faces to remove the face. This rectangle becomes the page boundary we need to work within. In the Links and Materials panel, rename OB:Plane to OB:A4pBoundary. (A4p being page size A4 Portrait)

Next we will set the camera to view this rectangle at the print resolution.

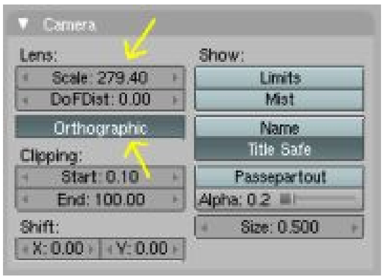
Press **N** to open the Transform Properties panel. Change RotX:, Y and Z as indicated.



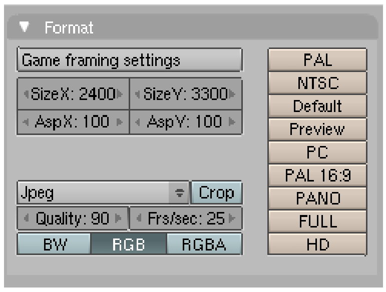
The Camera will now be parallel to the plane.

In the Camera panel (Editing Context Buttons) press Orthographic.

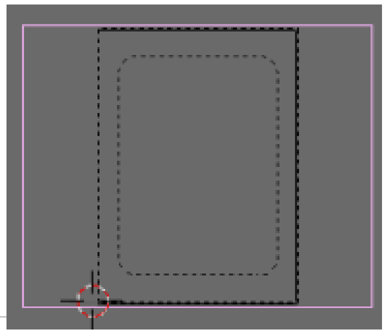
Set the scale to 279.4 (11 inches x 25.4mm)



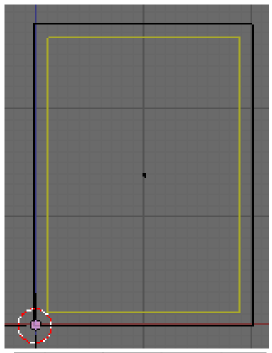
In the Format panel (Render Sub Context buttons) set sizeX: 240 (8 inches x 300 pixels) and SizeY: 3300 (11 inches x 300 pixels)



Select the camera and in camera view **NumPad 0**, move **G** the camera so that the outer dotted line aligns with the A4pBoundary.

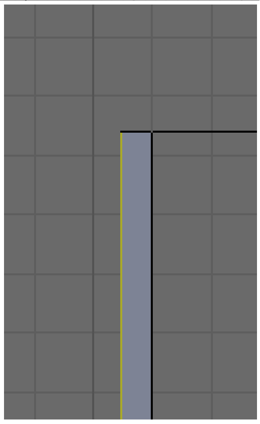


Select the A4pBoundary object **RMB** and copy it **Shift-D** then press **Esc** to leave it in its original position.

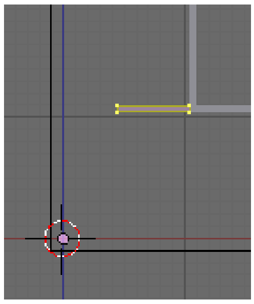


Tab into Edit Mode and in edge select mode select each edge individually and move it **G** 12mm towards the centre of the rectangle, constrained to the X or Y axis.

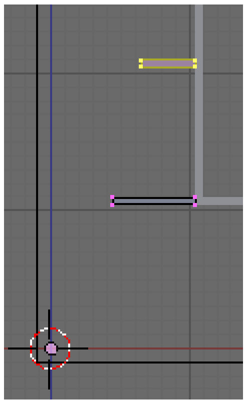
This rectangle will form our page border, it could now be rendered as a wire object but the output will only be one pixel wide, so we need to thicken the line.



Select the Left hand edge and extrude it -0.5mm on the X axis. Extrude the Right hand edge 0.5mm on the X axis. Box select the three edges making up the top of the border and extrude these 0.5mm on the Z axis and repeat this on the bottom edge but -0.5 on the Z axis.
Rename this object A4pBorder



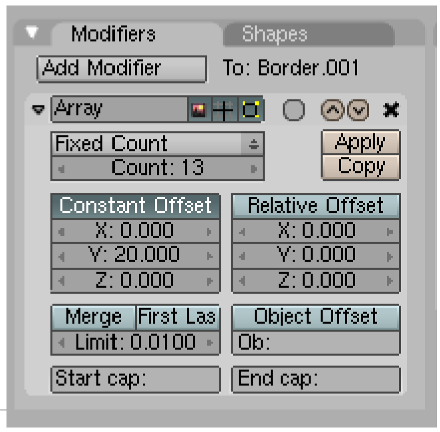
Tab into Object Mode and Add a new Plane **SpaceBar** Add>Mesh>Plane. This will be used to create the edge ruler's. Move the Plane to the bottom left corner of the A4pBorder and resize to X axis 6mm and Y axis 0.5mm.



Select all vertices **A** and copy **Shift-D** the vertices on the **Z** axis **10**mm.

This will form the marks for a ruler that runs along the outer edge of the border.

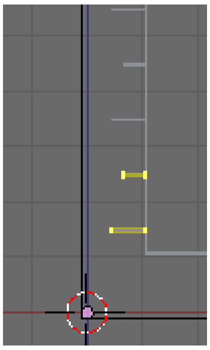
Grab **G** the two Left vertices and move them on the **X** axis **2**mm. then select all the vertices A.



In the Modifiers panel click Add Modifier and select Array from the pop up menu.

The Array modifier will copy the selection by the number set in the Count: field and offset each copy.

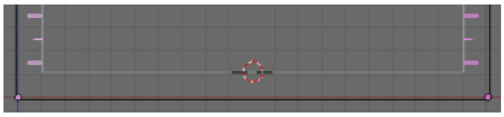
Set Count:13, De select Relative Offset, select Constant Offset and set Y:20. The selected lines will be copied up the side of the border.



Tab into Object Mode and select A4pBorder object. **Tab** into Edit Mode for this object and select one of the long bottom edges. Snap the cursor to the edge **Shift-S** Cursor>Selection. The cursor will be repositioned in the middle of the edge. **Tab** back into Object Mode.

Select the Plane object and copy it **Shift-D** then press **Esc** so it does not move position. Set the Pivot Point to Cursor select.

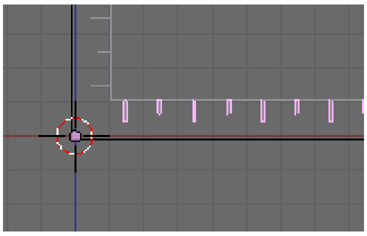
Mirror the copied edge ruler **Ctrl-M** and accept "X Local".



The Border rules will now be mirrored onto the right hand edge.

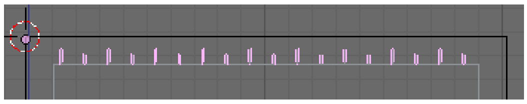
Select both border rulers and copy them **Shift-D** then rotate them 90 degrees **R-90**. These will form the top and bottom rulers.

Select the A4pBorder object and snap the cursor to the object centre **Shift-S** Cursor>Selection. Select the bottom ruler and snap this to the cursor **Shift-S** Selection>Cursor.

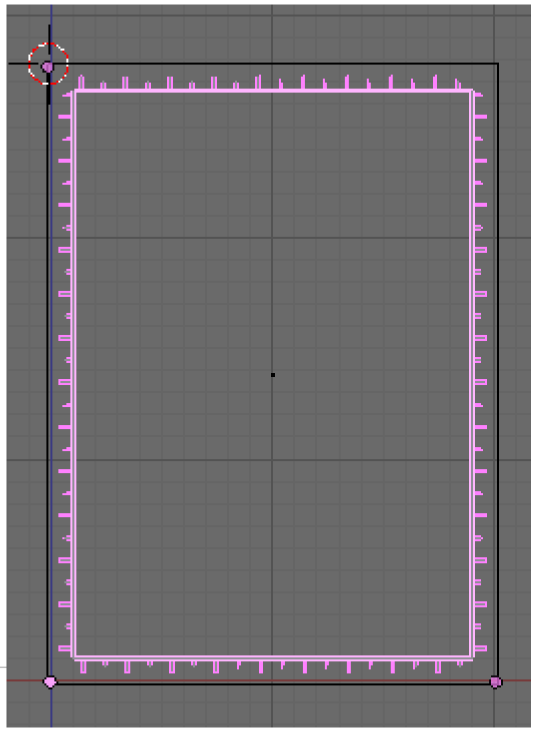


In the Modifier panel, reset the Array count to 9

Repeat this on the top edge but snap the cursor to the top left vertex of the A4pBorder object (*Edit Mode*).



It may be necessary to adjust the position slightly to ensure the rulers are touching the A4pBorder object.



It doesn't matter that the rulers overlap the border slightly, as we will be using a shadeless texture.

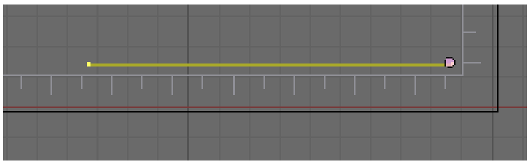
With the top ruler selected press Apply in the Array Modifier panel. This will convert the Array into a mesh objects.

Repeat this on the other three ruler's.

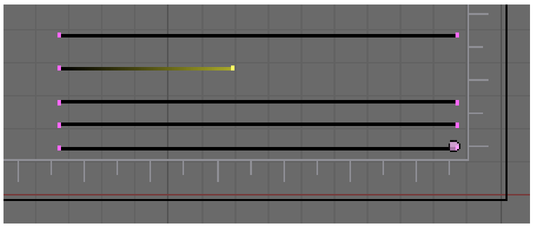
Shift-RMB Select all the rulers and the A4pBorder Object ensuring the A4pBorder was the last selection and join them into one mesh **Ctrl-J.**

All that's left now is the Title Box.

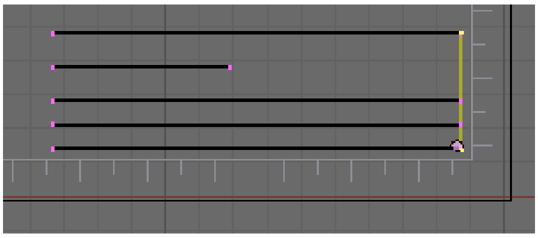
Add a Plane object and move it just inside the lower right hand corner. Resize the plane to 0.5mm high by around two thirds the width of the border. The exact size will be dependent on the text fields you want to put in it.



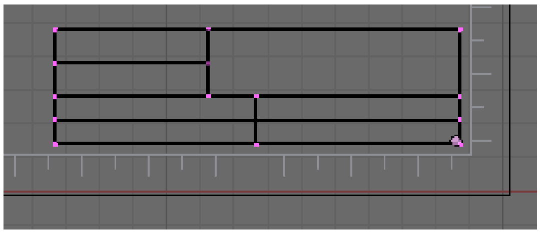
Copy the plane several times in the Z axis at a height to suit your text. I have used 7mm for the small text and 10mm for the larger text. Form a space for the title box by shortening one of the lines.



Copy one of the lines **Shift-D** and **R**otate it **90** degrees. Position it on the right hand side of the Title Box and adjust its length to suit the horizontal lines.

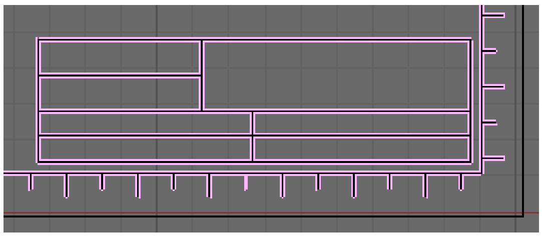


Copy this edge to form the other vertical edges and resize them as necessary.

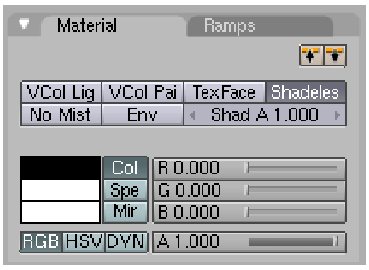


Tab into Object mode and with the Title Box selected, **Shift-RMB** select the A4pBorder object and join the meshes **Ctrl-J.**

The Border and Title Box are now one object.

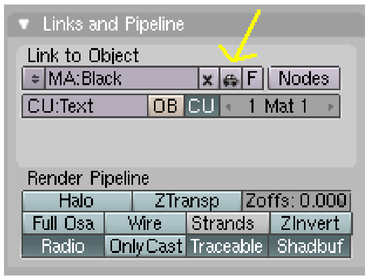


We now need to add a colour for the border.



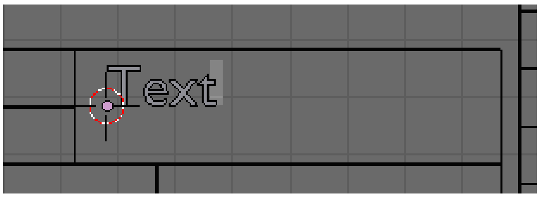
In the Materials tab of the Material sub context buttons, I have set R, G, B to 0 for a Black colour.

Select the shadeless button so the colour won't be affected by any lamps in the scene.

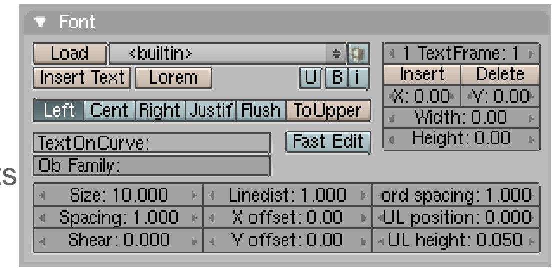


In the links and Pipeline panel press the small button with the car on it. This will give the Material an automatic name representative of the colour chosen. In this case Black.

We now need to add some test to the Title Box. **LMB** click over the Title Box to set the cursor position. Press the Space Bar to open the Toolbox and choose Add>Text, a text object will be placed on the view, but much to small to see.

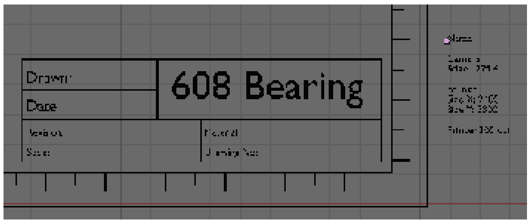


In the Font panel of the Editing Context Buttons change Size: to 10. **Backspace** to remove the word Text and type in **608 Bearing**. Scale **S** and move **G** the text so it fits in the Title Box.

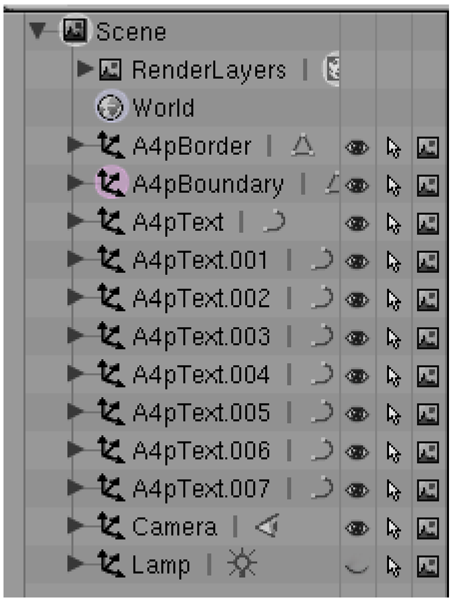


To add the same Black Material to the text in the Links and Pipeline tab, click the Arrow box to the left of Add New and select Black from the pop up menu. In the Link and Materials tab of the Editing buttons change the name from OB:Text to OB:A4pText.

Tab into Object Mode and copy the text **Shift-D** to another area of the Title Box and **S**cale it to fit. **Tab** into Edit Mode and **Backspace** to clear the text, then type in the new text. Repeat this for all the fields of the Title Box



One further useful addition is to copy a text object outside the Boundary object and type in the camera scale, Format size x and size Y and the printer dpi.



In the Outliner you will now have a grouped list of A4p objects that can be easily appended into any .blend file you are working on

The settings needed for the camera will be appended along with the Border

All that is left for you to do now is make more templates in different page sizes.

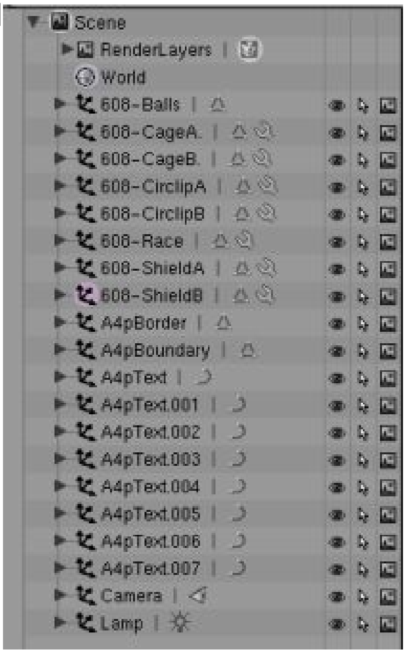
Finally save your work as PageTemplate.blend

Layers

Up to now everything has been produced on layer one of the twenty available layers within Blender. By organising your work onto different layers, Blender allows you to set different lighting and rendering parameters for objects on different layers. As we need to combine some of the objects rendered with the edge render facility of blender, together with others that do not use the edge setting we will need to organise our layers and render output.

Firstly we will set our scene. If you still have a .blend file open, save your work **Ctrl-W** and then open a new file **Ctrl-X**.
Save the new file **Ctrl-W** as "608-Layout.blend".

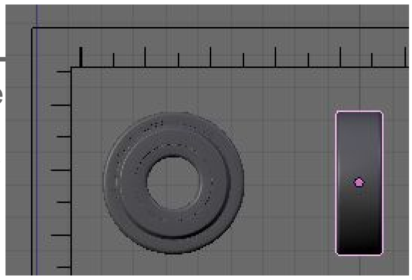
Append all the A4p objects from the PageTemplate.blend file produced in part 10. **Shift-F1** to open the File Browser window in Append mode and from the "PageTemplate.blend" file **LMB** click Object then **RMB** select all the A4p objects. Click on Load Library to bring them into the new file. They will be placed on Layer one, as this was the layer they were created on.

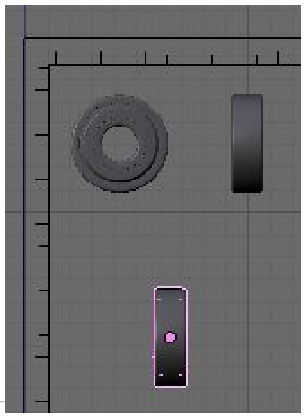


Now append all the parts of the 608 Bearing into the file. In front view **NumPad 1** select all the components of the bearing and move them **G** to the top left corner of the page template. As the bearing is only 22mm across we will scale it 2:1. With all the components still selected press **S** for scale then **2** for the scale factor. The bearing will double in size.

Open the Outliner as detailed in Part-4. All the components of the Border and Bearing will be listed.

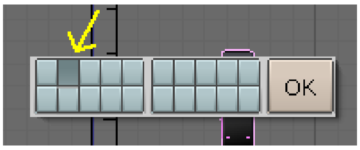
Copy the bearing *(all bearing components selected)* **Ctrl-D** and move the copy on the **X**-axis to the right hand side of the original. In top view **NumPad 7 R**otate the bearing **90** degrees. Go back into front view **NumPad 7**. We now have a front and side view, within the page border.



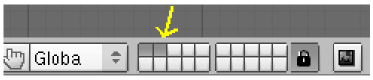


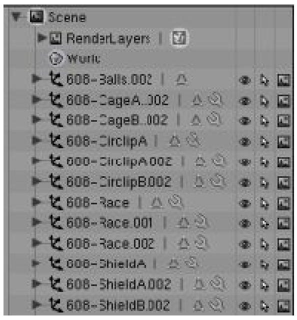
With the side view still selected copy the components and move them below the original. This will be used to create a part section through the bearing.

The Front, Side and Part Section view of the bearing needs to be rendered using Blenders edge render facility and therefore needs to be rendered separately from the rest of the layout.



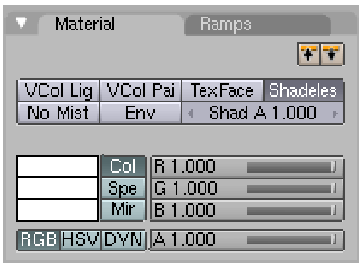
Box select the three bearings and press **M** which will open the Layer Move panel click on layer 2 and press OK. The two bearings will disappear from view until layer 2 is activated. To bring the bearings back into view, **Shift-LMB** on layer 2 in the view header's layers panel.



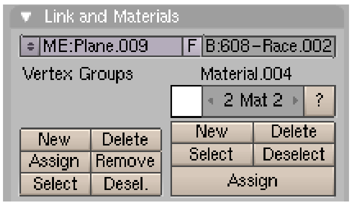


If your computer is slowing down due to the amount of detail in the bearing's you can delete the components that won't be seen. I have removed the balls, both cages the back dust shield and circlip from the front view and all but the 608-Race from the side view. The section view needs all the components.

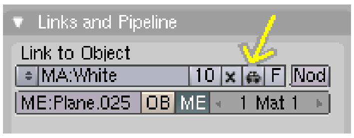
We now need to set the material to give a line drawing effect. Select the race of the side view and in the Material panel of the Material buttons, change Col to white *(click on the grey square next to it and choose white from the colour picker)*
Click Shadeles so the colour isn't affected by any lamps in the scene.



In the Link and Material panel of the Edit buttons select "2 Mat 2" to choose the second material and press Delete to delete it.



In the Links and Pipelines panel click on the small Car button to auto name the colour.

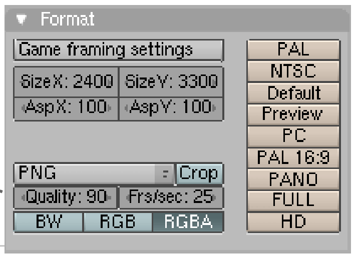


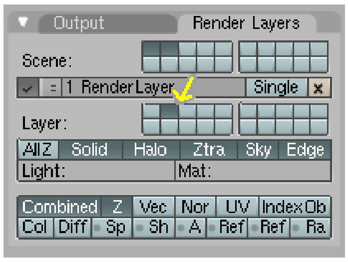
In the Mirror Trans tab make sure Ray Mirror is not selected.

In the Texture tab click Clear to remove the texture.

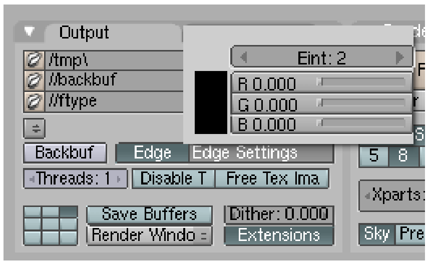
Change the SizeX: and SizeY: to those detailed on the page template, *(text outside the Page Border)*. Set the output to PNG and select RGBA.

The RGBA button will save the render with a transparent background allowing us to overlay the lined drawing over the standard render.





In the Render Layer tab of the Render Buttons click Layer 2 which will restrict the render to the objects on this layer.



On the Output tab click Edge and then Edge Settings.

In the Edge Settings pop up window change Eint: to 2.

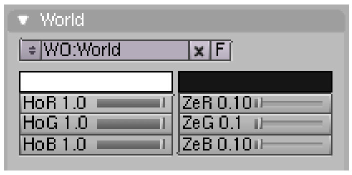
This will set the line intensity so it predominantly highlights the main edges.

Click on the Camera and in the Edit buttons Camera panel click on Orthographic to use the orthographic camera mode.

Set the scale to 279.4 as detailed on the page template.

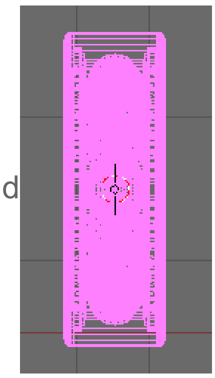
With the mouse over the 3D view press **N** to open the Transform Properties window and set the camera view parallel to the Page Template. RotX:90, Y:0, Z:0.

Align the Camera with the page boundary.



In the World panel of the Material buttons set the background colour to white.

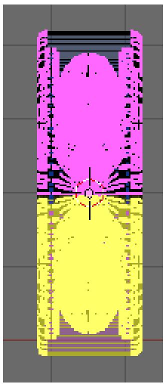
The Front and side view's are now set-up to give us a line render but before we do this we need to section and scale the Part Section view.



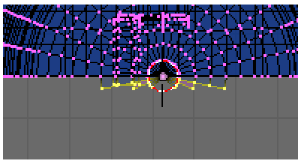
De select **A**ll then in wire view Box select the components of the bearing we are going to use for a section view.

Go into local view **NumPad /**. Then **Shift-RMB** the outer race and join all the components **Ctrl-J**.

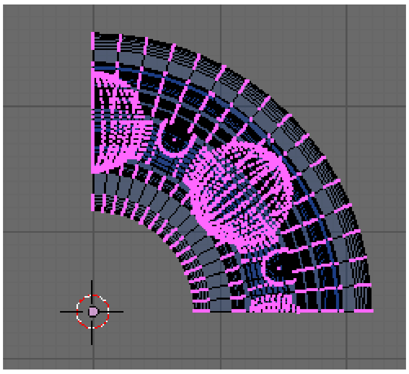
Its easier to cut through the bearing as a single mesh than to have to repeat the cuts for each component.



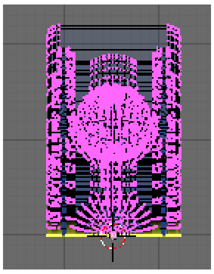
In top view **NumPad 7** De select **A**ll the vertices then **B**ox select all the vertices to the front of the bearing centre *(not the vertices on the centre line)*.
Delete **X** these vertices.



Zoom in **SW** on the centre of the bearing and delete any remaining vertices that were missed by the Box select.

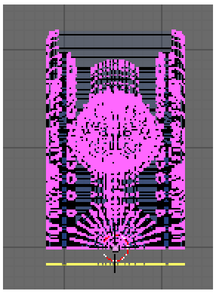


In front view **NumPad 1** repeat the process of selecting and deleting vertices. This time though remove the lower quadrant of the bearing
Not all the edges finish on the horizontal centre line. As only the inside diameter of the bearing will be seen at this location, make sure every vertex below the centre line is removed.



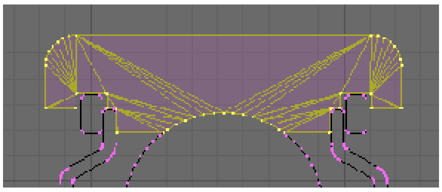
In top view **B**ox select the single row of vertices on the bearing centre line.

Copy these vertices **Shift-D** and move them on the **Y** axis forward of the bearing.



Separate them from the bearing **P**.

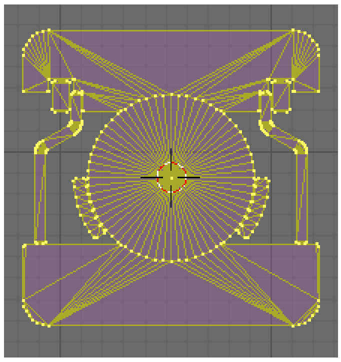
We will use this slice through the bearing to add the hatch pattern to the section view.



Tab into Object Mode and go into Global view **NumPad /**. select the slice through the bearing we have just created and go back into Local view **NumPad /** for this object. **Tab** into Edit Mode.

Link select **L** each closed area of the slice and fill the area **Shift-F** with faces. Beautify the fill **Alt-F** to give a cleaner mesh.

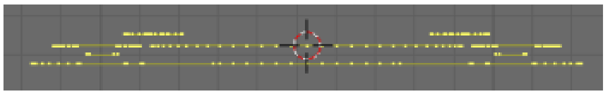
Press **A** to de-select the vertices then repeat the process on the next closed area.



Continue until all the faces of the section are filled.

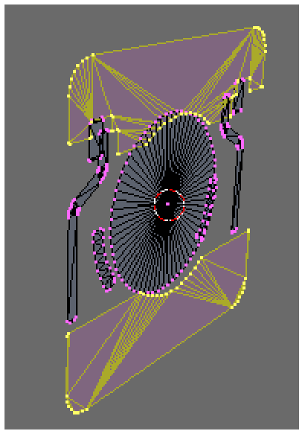
De-select **A**ll vertices.

Link select the two areas that represent the bearing race and in top view **NumPad 7** move them **G** forward of the other areas of the bearing, on the **Y** axis.



Repeat this for the other areas of the section making sure no two components touch each other on the same plane.

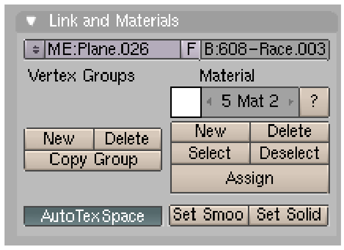
This is necessary so the Edge Render filter can detect the edge of each component.



Link select the inner and outer race sections.

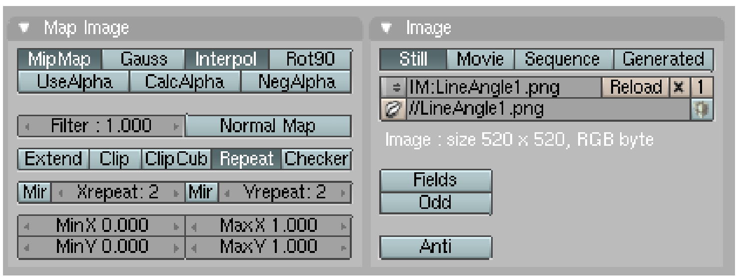
We are now going to add a hatch pattern to this area.

In the Link and Materials panel of the Editing buttons press "New" to add a new material.

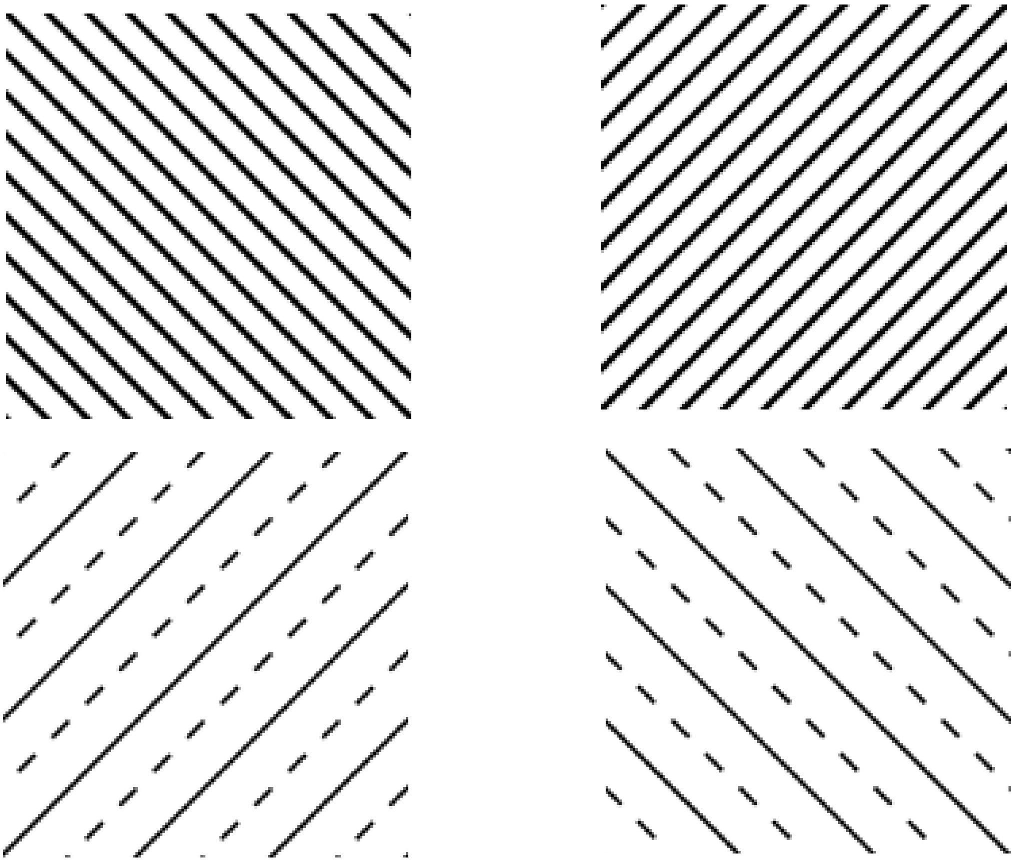


Press Assign to assign this material index to the selected vertices.

In the Texture Buttons Texture tab click the number next to the TE:Tex box and accept single user. Add New to add a new texture. In the Texture Type button click None and then select Image from the pop up menu.

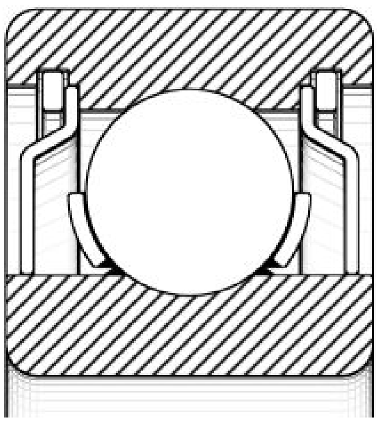


You will need to either create your own or download the hatch patterns from www.rab3d.com in Part-11 of the 608 bearing tutorial, download **RMB** Click on the hatch patterns and "Save Target As..." to save the images.



In the Image panel load "LineAngle1.png". To make the hatch render smaller, repeat the texture on the section by changing Xrepeat: and Yrepeat: to 2 in the Map Image panel.

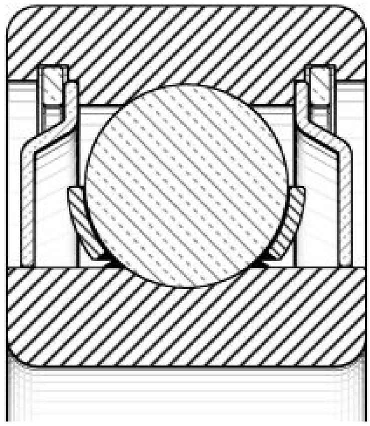
If you render the image at this stage a hatch pattern will be created on the bearing race.



To add further hatch patterns **L**ink select the area to hatch *(for this example both halves of the bearing cage)*. In the Links and Materials panel of the Edit Buttons Click "New" then "Assign". Material 3 has been created and assigned to the selected vertices. In the Texture panel set the texture to single user. In the Image panel of the Texture Buttons change the texture to "LineAngle2.png"

Repeat this process until all the section faces are filled with a hatch pattern.

Change Xrepeat and Y repeat to resize the textures.

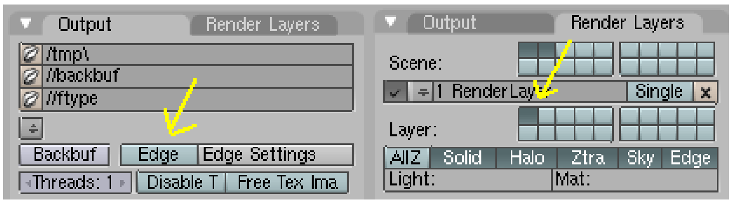


We are now ready to render the line drawing. In the Render Buttons, Render panel , press "Render". Or use the keyboard shortcut **F12**.

When complete close the Render window and save the image **F3** as 608-Line.png.

Save you work **Ctrl-W**

For the rest of the layout we won't need to use the edge rendering setup, so on the Render buttons Output tab de-select edge. In the Render Layers tab select layer 1

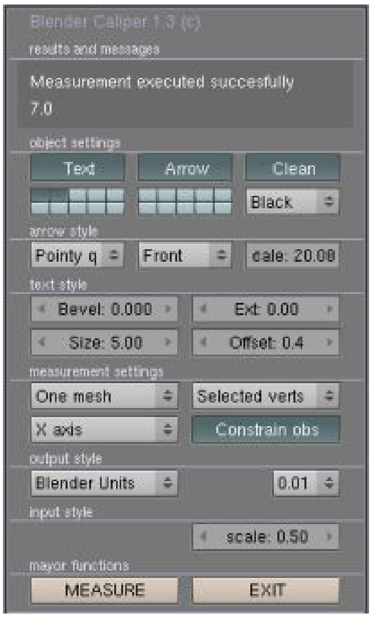


To add dimensions to the layout we will use the Blender Caliper script. The script doesn't come already loaded with blender but can be downloaded from alienhelpdesk.com

Follow the instructions on their site to load the script. And read the user documentation.

In blender split the view and open a script window as detailed for the Bevel script in part 4. But this time load the "Blender Caliper" script from the "Wizards" section of the scripts pop up list.

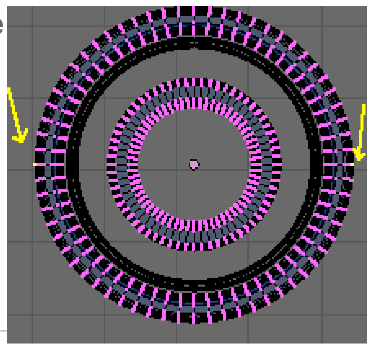
It may also be necessary to first click "Update Menus" from the same pop up list to register the script in Blender.



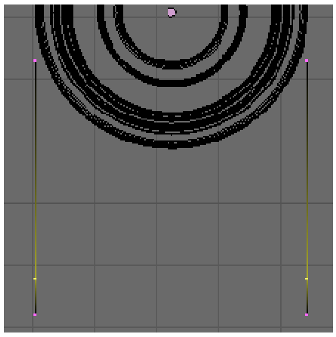
Before we can dimension the bearing we need to add some points to dimension.

In Edit Mode select **Shift-RMB** the two vertices at the widest point of the bearing on the same edge loop.

Copy these **Shift-D** in the **Z** axis below the bearing.

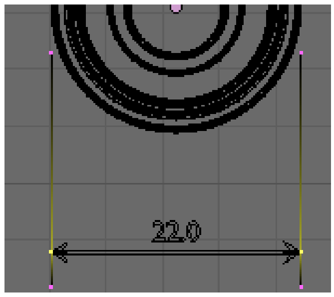


Extrude these vertices in the Z axis to the point where you want the dimension to be.

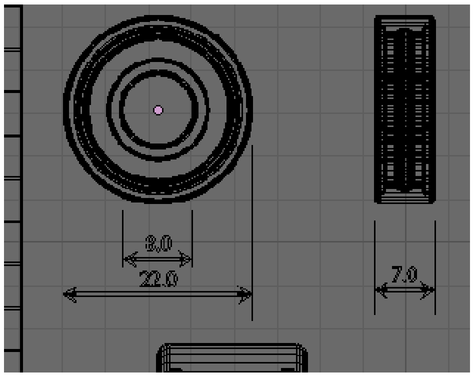


Then extrude them again so the dimension lines will pass the dimension arrow.
Shift-RMB select the 6 vertices of the dimension line and separate **P** them from the 608-race mesh.

Tab into Object Mode and select the Dimension Lines.
Tab back into Edit Mode for this object. In the Edit Buttons Link and Materials panel change the objects name to Dim.

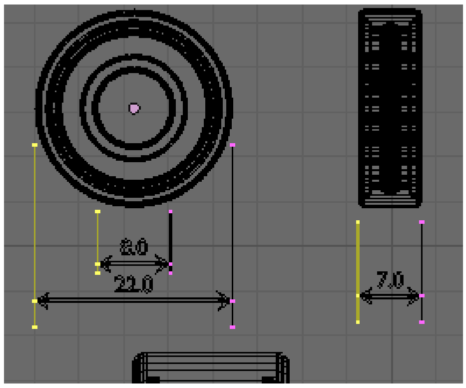


Select the two middle vertices of the dimension lines and with Blender Caliper set as indicated above press "Measure".



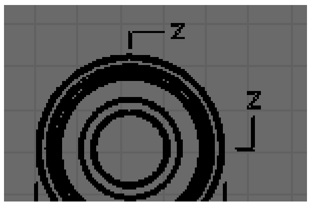
A dimension and arrowed line will be created.

Repeat this process for the other dimensions, then **Tab** into Object Mode and select all the dimension lines and Join them **Ctrl-J** to the Dim object.



Tab into Edit Mode for the Dim object and select all the vertices on the left hand dimension lines. To thicken these lines for rendering extrude them -0.2mm on the X axis.

Repeat this on the right hand lines extruding them 0.2mm on the x axis.



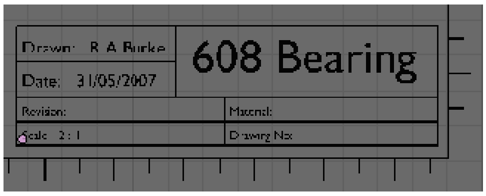
Link select one of the dimension lines and copy it **Shift-D**. Move it over the bearing and re shape it to form the section markers.

In the Material buttons Links and Pipeline panel change the material to Black.

In Object Mode copy one of the dimensions text objects and **Tab** into Edit Mode. Change the text to Z, **Tab** back into Object Mode. Move Z to the section marker. Copy this and move it to the other marker.

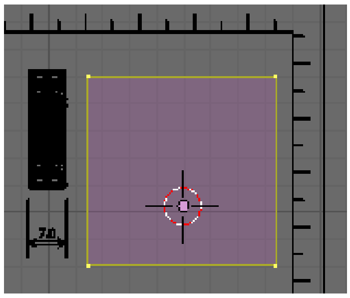
Select one of the dimension text objects and copy it to below the section view. Change the text as indicated and scale the text to a suitable size.

To finish editing text, fill in the fields in the Title Box.



The final part to the layout is to add the 3D image of the bearing created in Part 9, along with the exploded view.

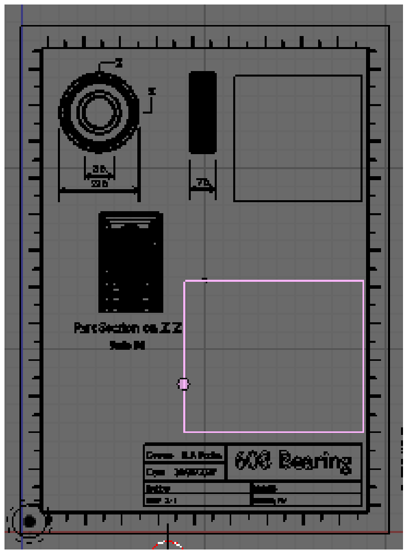
to do this add a Plane and Move it **G** to the top right corner of the layout. Scale the plane **Shift-S** to fit in the area next to the line drawing.



In the Material buttons Links and Pipeline panel add a new material. In the Material panel set the material to Shadeless.

In the Texture buttons Texture panel add a new texture. set the texture type to Image and in the Image panel load the rendered 3D view created in Part 9.

The image won't be visible on the plane until it is rendered.



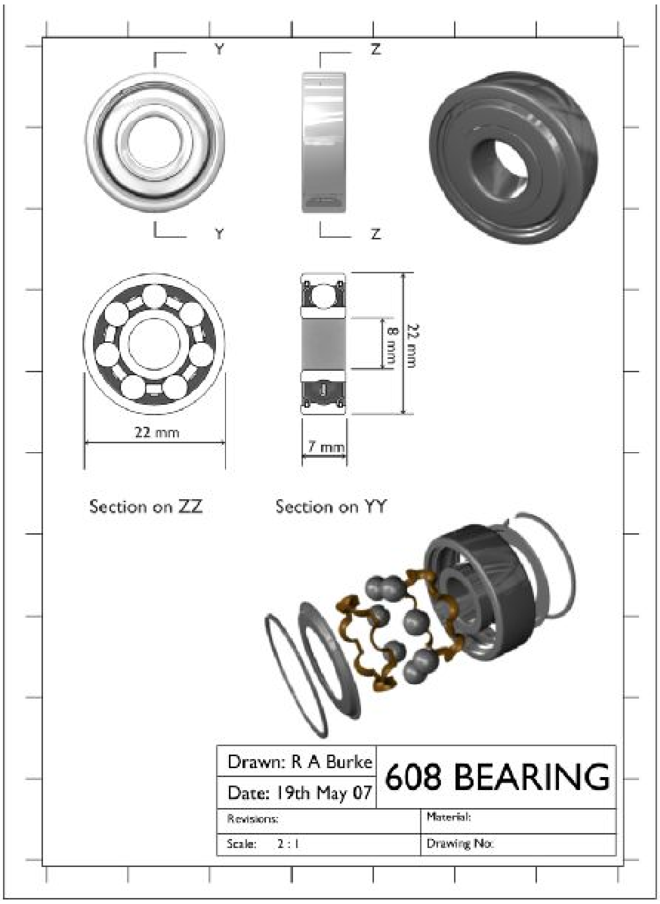
To ensure the Plain is set at the correct aspect ratio for the image, in Object Mode select the Plane and press Alt-V. The planes shape will change to suit the loaded image. Reposition the plane if necessary.

Add another Plane in the lower right area of the layout and repeat the above process but this time load the Exploded View.png from Part 9

If you render the Layout now F12 you will get an image with all the Layout elements except the line drawings.

In the Format panel of the Render Buttons leave the output as PNG but change the image format to RGB. We don't need an alpha channel on this image.

Press **F12** to render the image. Close the render window, press **F3** and save the image as 608-Layout.png



The final stage is to combine the 608-Line.png created above with the 608-Layout.png.

This can be carried out either using the Node Editor within Blender or by using an external image editing program such as gimp.

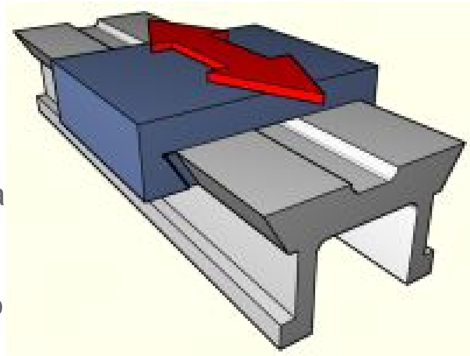
The Node Editor is to complex to cover in this part of the tutorial so, In the image editor of your choice open both 608-Layout.png and 608-Line.png. Copy 608-Line.png to the clipboard and paste it into 608-Layout.png as a new layer. The line drawing will sit over the layout drawings without obscuring them because it was saves with a transparent background. Finally in the Image Editing program resize the image to 300 dpi.

The final result gives a good layout drawing, easily capable of communicating the essential elements of a product design. With sufficient planning and forethought any component could be created, rendered and dimensioned in Blender.

Part 1 Guide Roller Design Concept

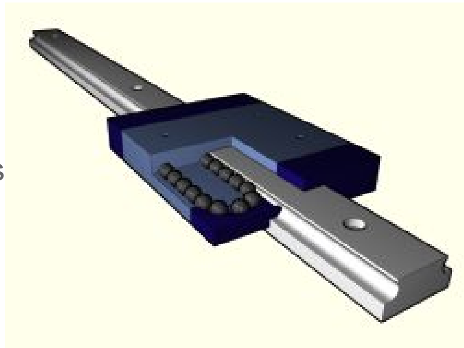
Linear Guides

Many engineering situations require the movement of machine parts along set axes. On traditional machine tools this was historically achieved by using accurately machined and hand scraped guides that run on planed or ground slides. This method of construction when done correctly offers a great deal of rigidity between the components but still allowing movement in one axis. The drawback of this type of slide is the initial high load required to overcome the starting friction. On a traditional machine tool this simply meant the operator would have to exert a little more force on the hand wheel to start the slide moving.



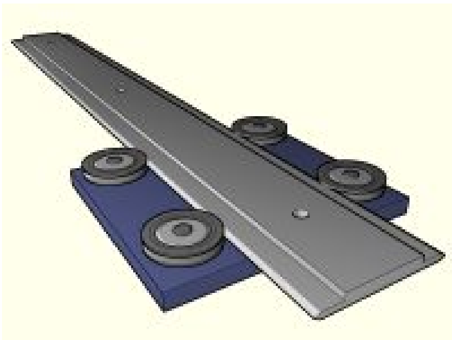
Traditional Dovetail Slide

On Industrial CNC machines overcoming friction to allow increased speed and or smaller drive units has brought about the development of linear bearings. These usually contain re-circulating balls or rollers that run along hardened and ground guides. Alternatively larger drive units are fitted to traditional slide ways. In both situations overcoming friction can be a costly process.



Re-circulating Ball Guide

As an alternative to recirculating ball races, some industrial processes use a ‘V’ roller guide running on a pre formed track. Though not offering the same rigidity or accuracy of the recirculating ball races they are perfectly adequate for a light duty machine.



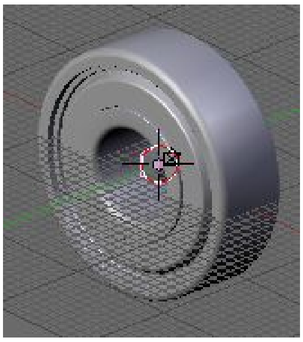
V-Roller Guide

As a hobby engineer the use of expensive OEM components such as linear bearings is not affordable, therefore an alternative must be used. The original router used “Oilite Bushes” running on 18mm Bright drawn steel shafts. The shafts proved amply strong enough for the job. The problem was the inability of the stepper motors to overcome the starting friction, especially when the shafts became slightly contaminated with dust from the machining process.

Though Industrial 'V' rollers are still quite expensive it is a simple process to machine an alternative that will run on the existing 18mm BDMS slides. The following tutorial shows how the 608 bearing model was used as a base to construct the ‘V’ roller and axle.

If you are currently using Blender save your work **Ctrl-W** and start a new project **Ctrl-X**. Delete the default cube **X**.

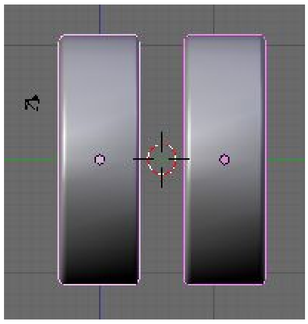
This section assumes you have completed and understood the 608-Bearing tutorial.



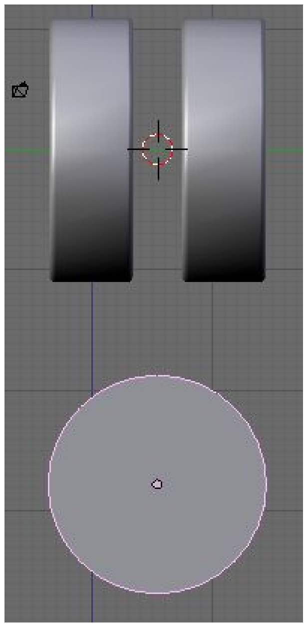
As the components will be built from the 608 Bearing geometry the first step is to append the low vertices 608 bearing into the scene. Press **Shift-F1** and navigate to the folder containing the 608-BearingSmall.blend made in the Bearing tutorial. Click on Object and select the OB:608-BearingSmall model, Press Load Library and the Bearing will be loaded into the scene. *(A more detailed description of appending is given in 608-Part 8.)*

Split the 3D view and open an Outliner window. *(If you cant remember how this is done it is described in 608-Part 4.)*

Some of the design constraints I have are based on the material available to me. I currently have slides at 18mm diameter so I will reuse these. The 'V' Roller will be made the same width as the slide to maintain as small a footprint as possible. I have some 45mm diameter BDMS that I will use for the rollers, so I need to make sure the outside diameter is less than this.

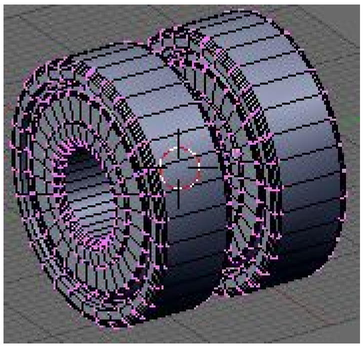


In side view **NumPad 3** Copy the Bearing **Shift-D** and move it in the **Y**-axis **11**mm. This will set the bearings with an external width of 18mm.



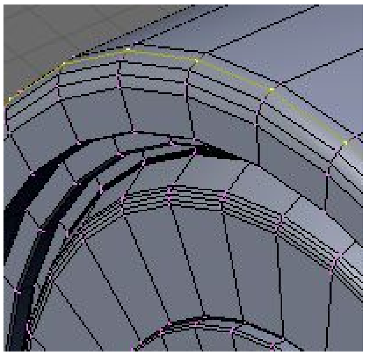
Next we need to add a cylinder to represent the 18mm diameter slide, centrally to the bearings. **Shift-RMB** select both Bearings and snap the cursor to the middle of them **Shift-S** Cursor>Selection. Add a Cylinder press **Space Bar** to open the Toolbox then select Add > Mesh > Cylinder. From the popup menu change radius to 9 and length to 20, press Enter to accept. Tab back into Object Mode and with the cylinder still selected, move it below the bearings **G** (move) **Z** to constrain it to the Z-axis and drag it to a position below the bearings.

We will now use the outer profile of the bearings to form the bore of the V-roller. **Shift-RMB** select both bearings and copy them **Shift-D** then press **Esc** to leave the copy over the top of the original bearings. With the two new bearings still selected join them into one object **Ctrl-J**. In the Link and materials panel rename the object OB:V-Roller. Press **NumPad /** to go into local view for the V-Roller and **Tab** into Edit Mode.

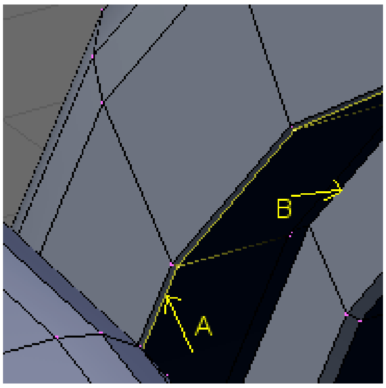


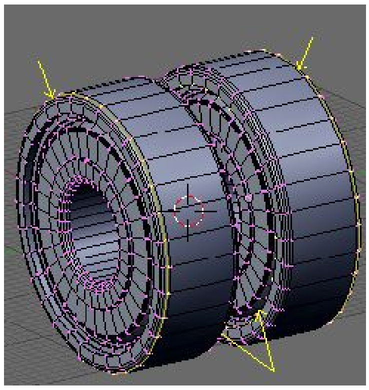
Now is also a good time to save your work. Pres **Ctrl-W** and save the file as V-Roller.blend

Shift-Alt-RMB Select the second outer loops of vertices from the bearing outside diameter and the loops indicated between the bearings. If you added chamfers to the bearing choose loop A otherwise choose loop B.
In total 4 loops should be selected.

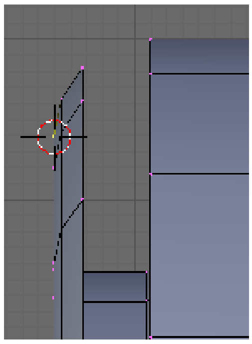


Delete these 4 loops **X** *Vertices*. This will isolate the outer section, from the inner part of the bearing.

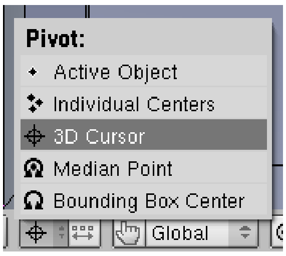




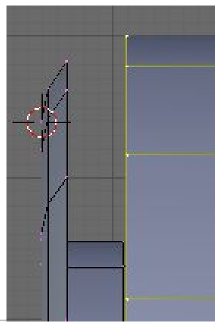
RMB select a vertex on the far left side of the bearing and snap the cursor to it **Shift-S** Cursor>Selection.

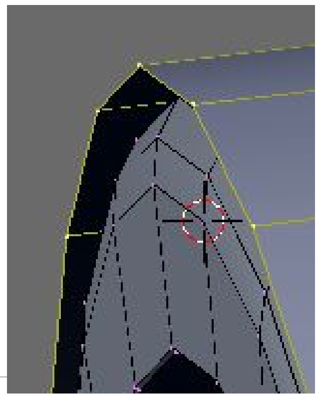


Change the Pivot point to 3D Cursor.



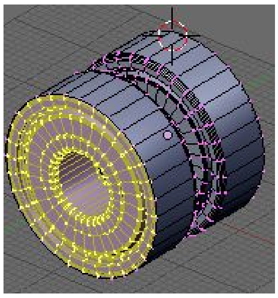
Alt-RMB select the loop of vertices on the outside diameter of the bearing. **S**cale these along the **Y-**axis to the **0** cursor position.





Repeat this on the Right hand side of the other bearing.

Press **A** to deselect all vertices then with the cursor over the inner portion of a bearing press **L** to select all linked vertices.

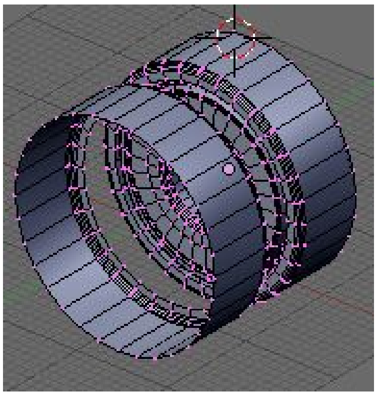


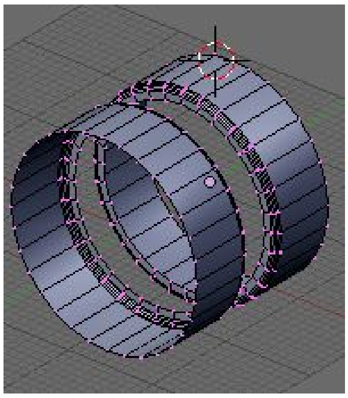
Delete the selected Vertices **X**.

Repeat this on the other Bearing.

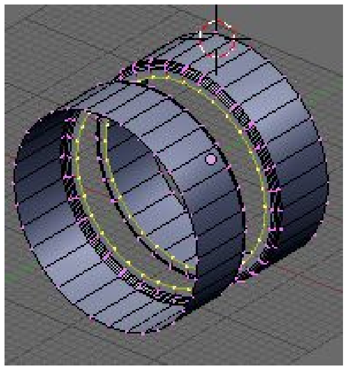
You are now left with two bores where the bearings sit inside the V-Roller.

These now need to be joined together.

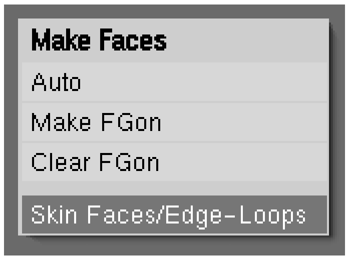




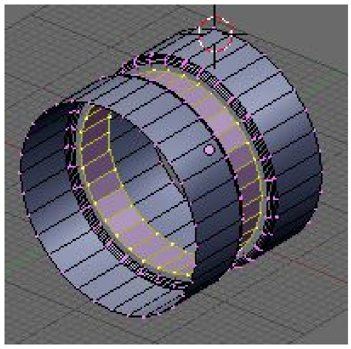
Shift-Alt-RMB select the inner loop of both bearings.



Press **F** to open the Make Faces menu. A new option is available Skin Faces/Edge-Loops.

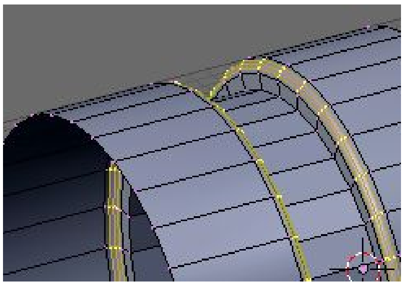


Pressing the Skin option will automatically build faces between the two vertex loops. It works the same as the Loft function in many 3D CAD packages.

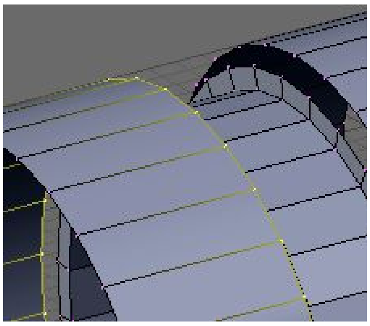


The bore of the V-Roller could be called finished at this stage, but its not really good engineering practice to have the inner fillet radius of a bore the same size as the object that is going to fit into it.

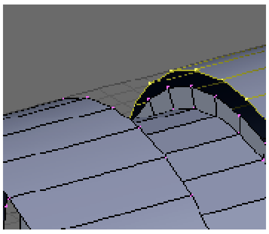
To facilitate a better fit for the bearing it is better to have a bore fillet with a smaller radius than that of the bearings outer edge. To achieve this we need to delete the loops making up the fillet and re model them.



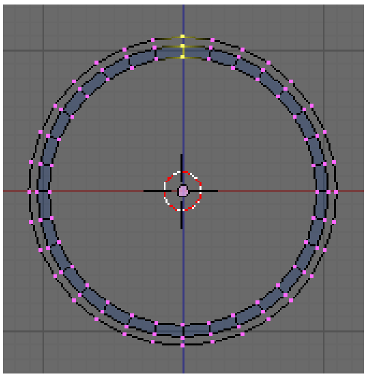
Shift-Alt-RB Select the inner loops of the two fillets and delete them **X.**



RMB select the inner loop of the left hand bearing location and move the loop **G** on the **Y-**axis **0.3**mm. This will allow us to reconstruct the fillet with a radius of 0.3mm, half the size of the outer fillet on the bearing.



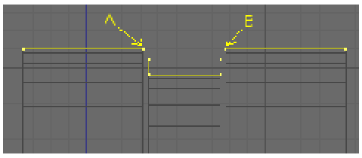
Select the inner loop of the right hand bearing location and move this -0.3 on the Y-axis.

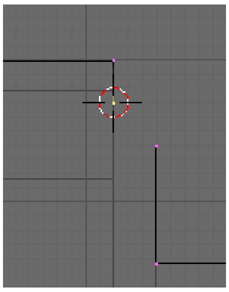


In front view **NumPad 1** press **Z** for wire frame view then **B-B** to open the paint select tool, select the top vertices.

Hide all the other vertices **Shift-H**.

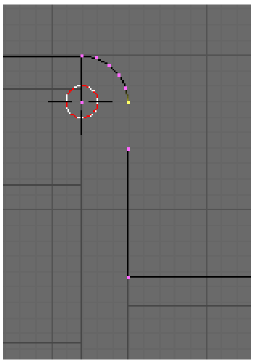
Go into side view NumPad 3 and RMB select the first vertex that will be used to spin the new fillet radius (A) and Extrude it on the Z axis -0.3mm. This gives us the centre point for the fillet.



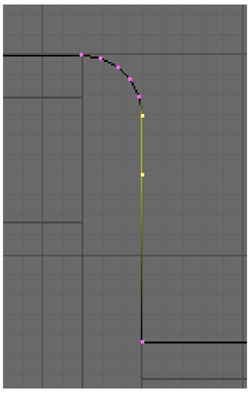


Snap the cursor to the extruded vertex Shift-S Cursor>Selection.

Reselect vertex A *(the vertex we are going to spin to make the new radius)* and in the Mesh Tools panel set Degr:90 and Steps:5, Press "Spin" to form the new radius.

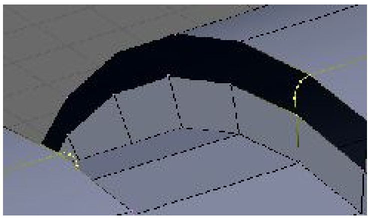


Select the vertex on the fillet centre and delete it **X**.



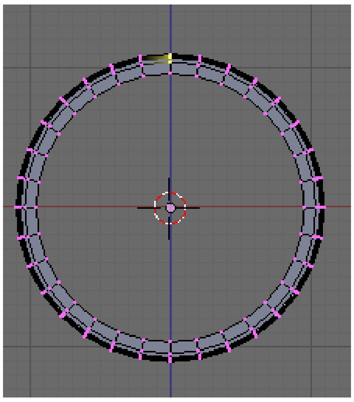
elect the two vertices shown opposite and add an edge between them **F**.

Repeat this for the Right hand side, selecting vertex B, but in the Mesh Tools panel deselect "Clockwise" so the fillet is spun in the opposite direction.



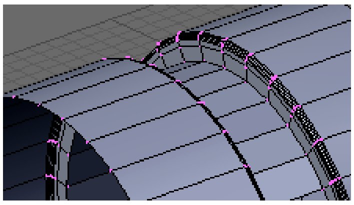
Shift-RMB select both sets of fillet vertices including those that join to the existing V-Roller bore.

Go into front view **NumPad 1** and **Tab** into Object Mode.



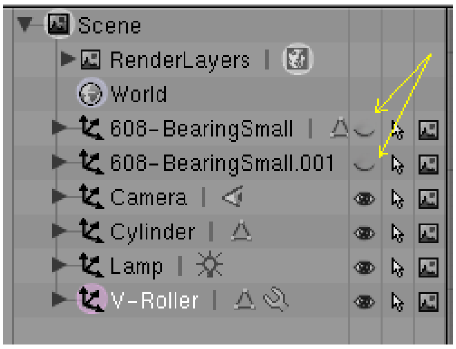
Snap the cursor to the Object Centre **Shift-S** Cursor>Selection then **Tab** back into Edit Mode.

In the Mesh Tools panel set Degr:360 and Steps:32, press spin to generate the new fillet. Select **A**ll and Remove Doubles **W**.

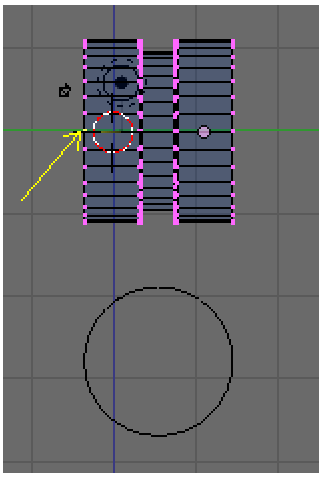


The bore fillet will now be at the smaller size.

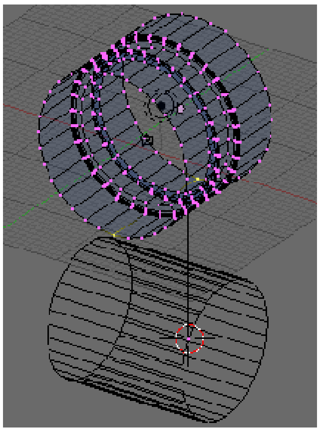
Go back into Global View **NumPad /** and you will see the bearings sitting in the newly created bore. At this stage we don't need the Bearings in the view. In the Outliner click on the eye icon for the bearings which will close, and remove them from view.



In side view NumPad 3 select one vertex that is sitting on the V-Rollers horizontal centreline. Extrude this vertex in the Z-axis -22mm, snap the cursor to this vertex. This will be used as a reference to set the outside diameter.



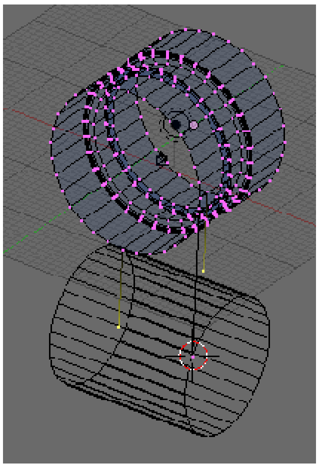
Select the two bottom vertices on the outer edges of the V-Roller. We will build the cross section of the V-Roller from these.



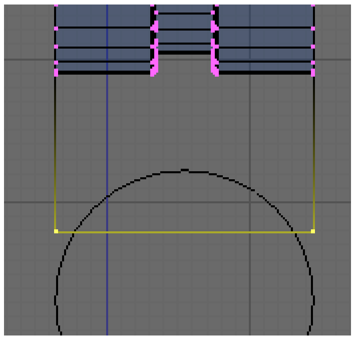
Extrude the two bottom vertices in the **Z-**axis with a length similar to the reference vertex.

To position them at the same Z-axis location as the reference vertex **S**cale them constrained to **Z** and to a scale location of **0**.

Delete **X** the reference vertex.

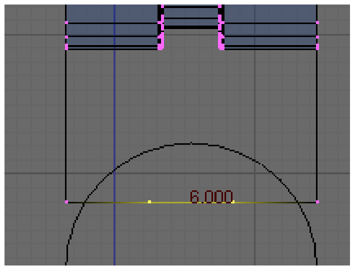


Add an edge between the two new vertices.

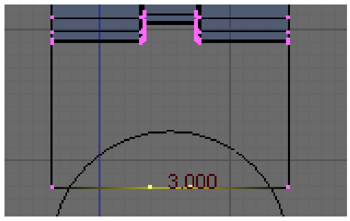


Subdivide Multi **W** the bottom edge with 2 divisions.

This will split the bottom edge into three equal divisions of 6mm each.



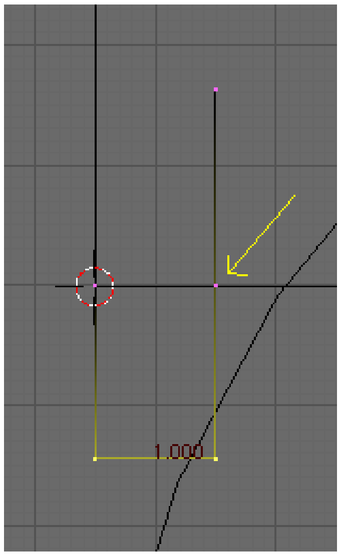
In order to cut the angles on the roller we first need to cut a central groove. On my lathe I will do this with a 3mm parting tool. To add the groove select the two central vertices. Change the Pivot to "Median point" and scale them by a factor of 0.5



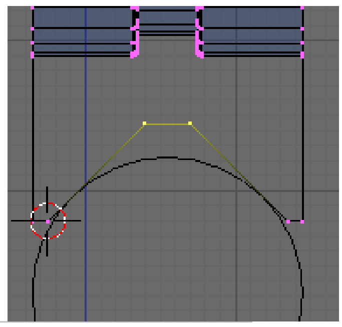
To give a small flat at the edge of the V-Roller **E**xtrude the bottom left corner vertex in the -**Z** direction then **E**xtrude this vertex in the **Y**-axis **1**mm, then **E**xtrude this vertically crossing the bottom edge. This will be used to cut a new vertex 1mm from the corner of the bottom edge.

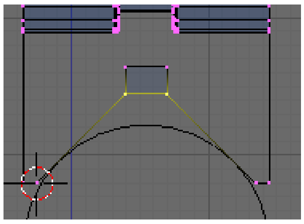
Select All the press **K** for the Knife tool, select Knife (Exact) from the sub menu and holding down **Ctrl** snap the cut line to the reference edge crossing the bottom edge. A new vertex will be created. Delete **X** the reference vertices.

Repeat this to cut a vertex from the right hand corner.

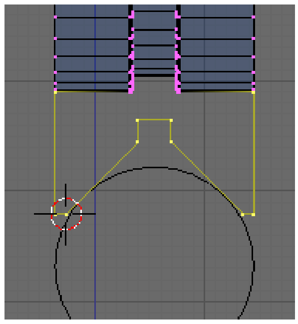


Select the two centre vertices and move them **G** in the **Z-**axis **6.5**mm. This will create the V profile with an angle of 45 degrees.

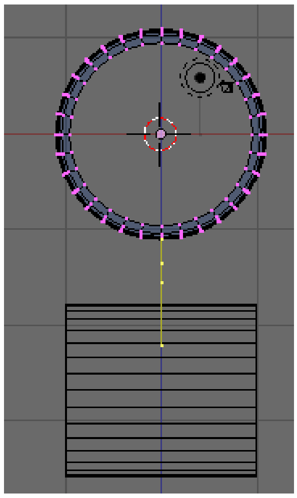




To complete the groove **E**xtrude "Only Edges" the central edge in the **Z**-axis **2**mm, then delete the lower central edge **X** "Edges".

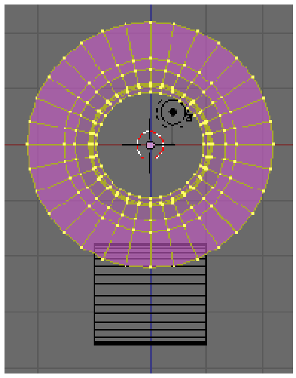


The roller profile is now ready to spin around the central axis. Select all the vertices of the profile, including those attached to the bore.



Go into front view **NumPad 1** and **Tab** into Object Mode. Snap the cursor to the object centre **Shift-S** Cursor>Selection, then **Tab** back into Edit Mode.

In the Mesh Tools panel set Degr:360 and Steps:32, then press Spin.

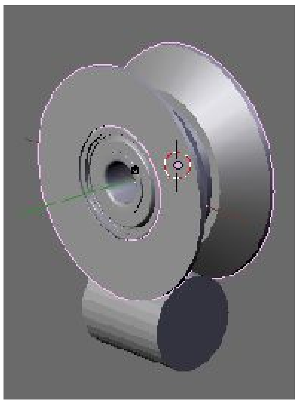


The profile will be created around the bore. Select **A**ll, Remove Doubles **W** and Set Smooth **W**.

In the Modifiers Tab ass an Edge Split modifier and keep the default settings. *(A more detailed description of adding the Edge Split modifier is contained in 608-Part 4)*

The V-Roller is now complete. In the Outliner open the eye icon for the two bearings to bring them into the view.

Save your work **Ctrl-W**

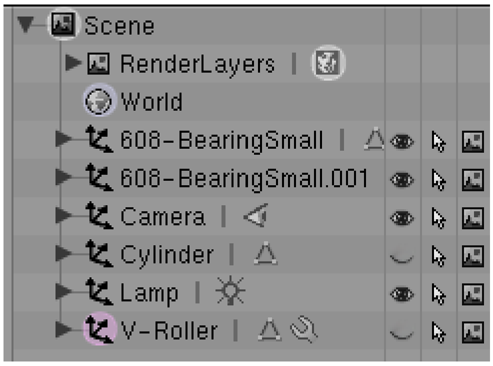


This has been a fairly long-winded way to construct the roller, however I have chosen to do it this way to introduce the Skin Face/Edge loops tool and methods to accurately modify a 3D mesh. In practice it would be much Quicker to simply construct a complete cross section and spin it around the centre axis.

In the next section we will construct the axle.

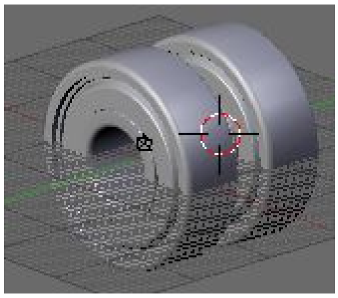
Guide Roller Part-2 The Guide Roller Axle

We have now got the V-Roller with two bearings inside it, so the next thing is to design the axle. I intend to make aluminium castings to hold four rollers and the lead screw nut and at this stage a casting thickness of 10mm seems appropriate. One end of the axle needs to fit into the casting the other end needs to hold the bearings. These are the governing factors for the length and profile of the axle.

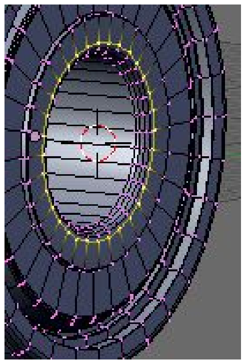


If it is not still open from part one, open V-Roller.blend.

In the Outliner make sure the eye icon is open for the two bearings and closed for the V-Roller and Cylinder.

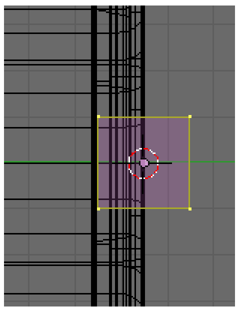


We only need the bearings in view to position the Object Centre for the axle and the section of the axle profile that the bearings sit on.

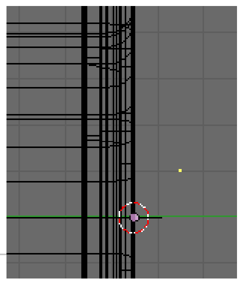


RMB Select the right hand bearing and **Tab** into Edit Mode. **Alt-RMB** select a loop of vertices on the outer right hand edge of the bearing and snap the cursor to the centre of this loop of vertices **Shift-S** Cursor>Selection. **Tab** back into Object Mode.

Go into side view **NumPad 3**.



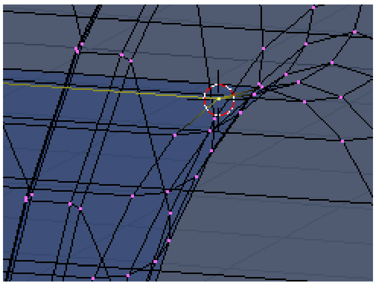
Press the **Space Bar** and from the Toolbox menu select Add>Mesh>Plane. In the Link and Materials panel change the name to OB:V-RollerAxle.



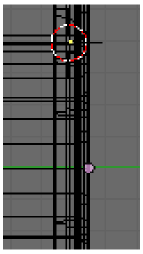
Shift-RMB the top right hand vertex to deselect it, then press **X** to delete the remaining three vertices.

RMB the remaining vertex to select it, then **Tab** into Object Mode. *(The vertex will be easier to locate when we Tab back into Edit Mode for the V-RollerAxle)*.

Select the right hand bearing and **Tab** into Edit Mode for this object. Select the top right hand vertex of the bearing bore *(the vertex on the bearing bore not one of the fillet vertices, check you have the correct vertex in front view **NumPad 1**)*, snap the cursor to this vertex **Shift-S** Cursor>Selection. **Tab** back into Object Mode.

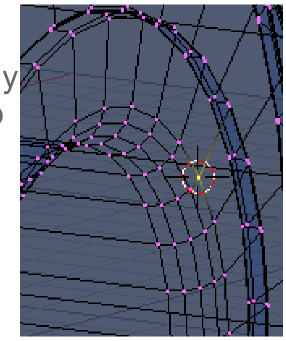


In the Outliner select V-RollerAxle and **Tab** into Edit Mode. The single vertex is selected so snap it to the cursor **Shift-S** Selection>Cursor. **Tab** back into Object Mode.



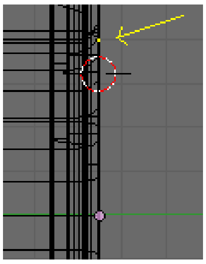
Select the Right Hand Bearing and **Tab** into Edit Mode. Select any vertex on the outer right hand edge and snap the cursor to it. **Tab** back into Object Mode.

In the Outliner select V-RollerAxle and **Tab** into Edit Mode.



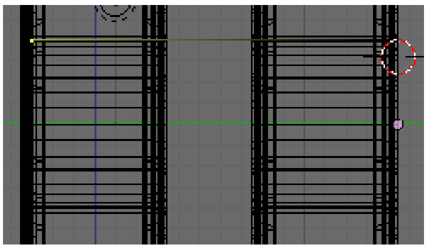
Make sure the pivot point is set to 3D cursor.

With the single vertex still selected **S**cale the vertex along the **Y**-axis to the cursor position **0**.

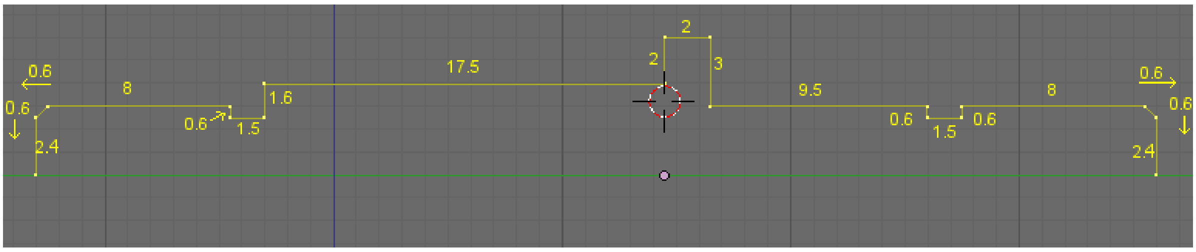


The vertex is now positioned aligned to the bearing bore and right hand edge. In side view **NumPad 3** **E**xtrude the vertex along the **Y** axis **-17.5**mm. **RMB** select the right hand vertex and **E**xtrude it along the **Z**-axis **2**mm.

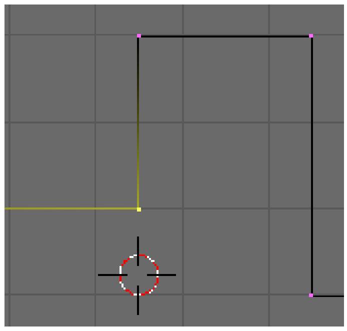
In the Outliner close the eye icon for the two bearings to remove them from view.



You are left with two edges that when spun around the Object Centre will form the bearing location area of the axle.

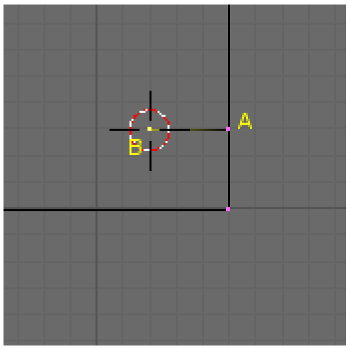


From the two edges that were positioned on the bearing bore extrude the following profile constraining the extrusions to the Y or Z-axis and dimensions indicated. The end chamfers are created by extruding 0.6mm in the Y-axis then grabbing and moving the vertex -0.6mm in the Z-axis. When complete this will form the basic profile of the axle.



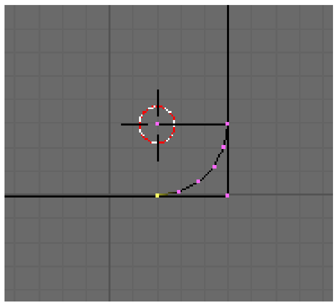
A little more refinement is required before we spin the axle around the Object Centre. Fillet radius and chamfers need to be added.

First we will add a fillet radius of 0.3mm to the inside angle of the central up-stand.

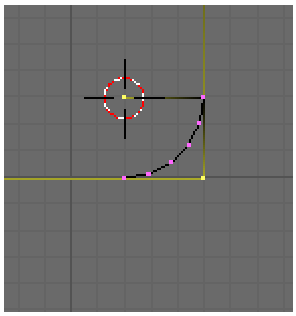


Select the inner corner vertex indicated and **E**xtrude this in the **Z**-axis **0.3**mm to point A *(vertex to spin)*, then extrude this vertex to point B *(fillet centre)*.

Snap the cursor to the vertex on the centre point.



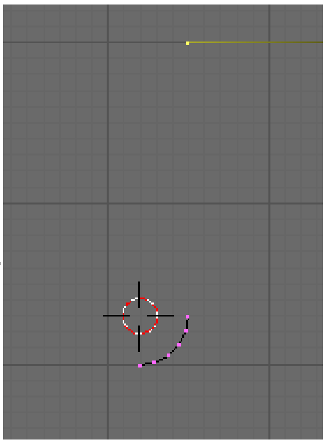
In the Mesh Tools panel set Degr:90 and Steps:5, then press Spin. The corner fillet will be formed.

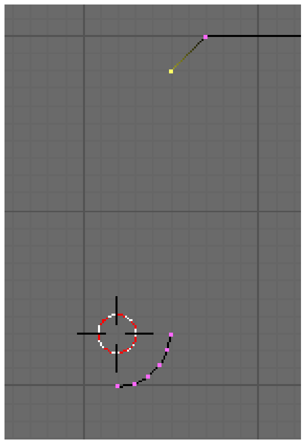


Select the corner vertex and the fillet centre vertex (B) and delete them.

Before connecting the fillet to the rest of the axle we can add a chamfer to the top edge.

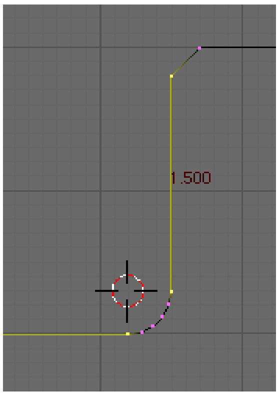
Select the vertex on the top edge above the fillet and move it **G** along the **Y**-axis **0.2**mm. Now **E**xtrude this vertex **Y -0.2**, then **G**rab this and move it **Z -0.2** A 45-degree chamfer has been added to the edge.

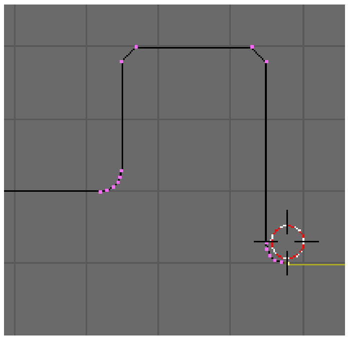




Reconnect the other end of the fillet to the end of the bearing location.

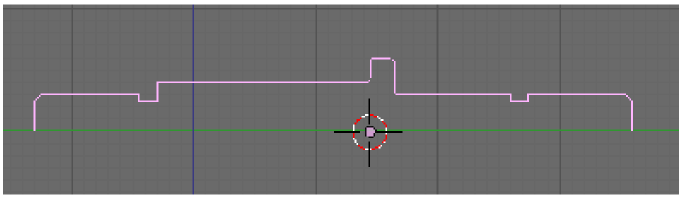
Add a similar fillet and chamfer to the other side of the central up-stand.





Tab into Object Mode and snap the cursor to the Object Centre.

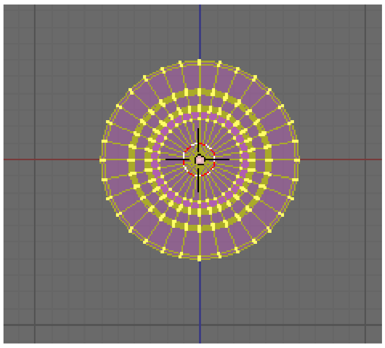
Tab back into Edit mode.



Go into front view **NumPad 1** and select All vertices.

In the Mesh Tools panel set Degr:360 and Steps:32, then press Spin. The axle will be formed.

When fitting the axle into the casting we need to be able to stop it rotating whilst tightening the retaining nut. The next step will be to add some spanner flats to the central flange.

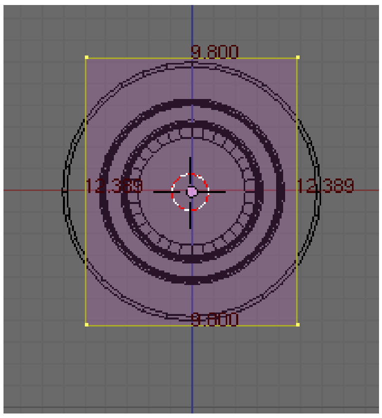


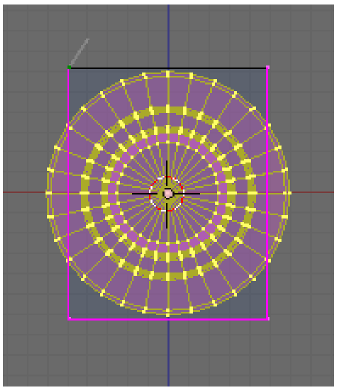
Tab into Object Mode and add a Plane. Select the two right hand vertices and move them **G** on the **X**-axis **3.9**mm.

Select the two left hand vertices and move these -3.9mm on the X-axis.

This will create a guide to cut flats 9.8mm apart for a 10mm spanner.

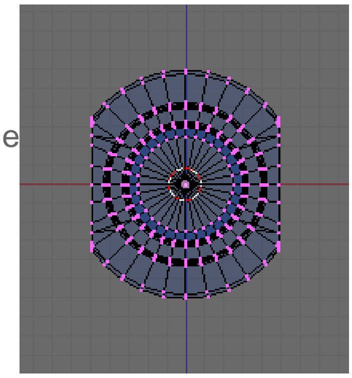
Select **A**ll and **S**cale the Plane on the **Z**-axis till it is larger than the flange.





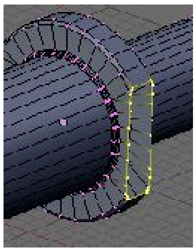
Tab back into Object Mode and with the Plane still selected **Shift-RMB** select the axle. Combine the two Objects into one **Ctrl J**.

Tab back into Edit Mode and cut new vertices to form the two spanner flats **K**nife (Exact) snapping the cut to the vertices of the plane **Ctrl-LMB**.

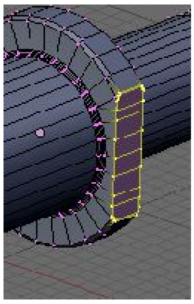


De-select **A**ll, then **B**ox select the vertices that are outside the spanner flats.

Delete **X** these vertices.

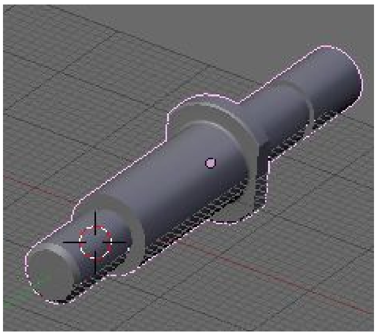


Shift-Alt-RMB select the loop of vertices around the opening of the spanner flat.



Add faces to the opening **Shift-F**, then beautify the fill **Alt-F** and then convert the created triangles to quads **Alt-J**.

Repeat this on the other spanner flat.



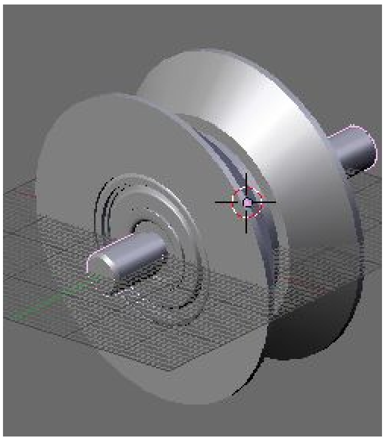
To complete the axle select **A**ll vertices, Remove doubles **W** and Set Smooth **W**. You may also need to recalculate the normals to the outside **Ctrl-N**.

To create a smooth surface with sharp edges, add an Edge Split modifier with the default settings.

Press **Ctrl-W** and save your work.

At this stage I have deliberately left the axle with plane ends rather than generating a threaded profile. In large assemblies the axle will use substantially less computer overheads than one with a detailed thread profile.

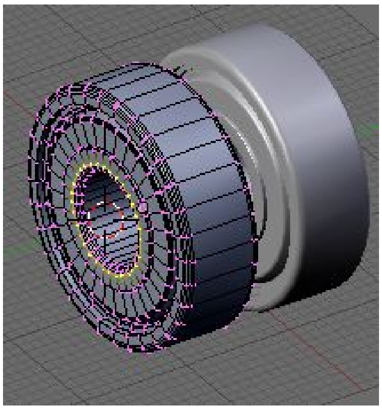
In part 3, I will detail how to set up and use the screw function to create a detailed thread suitable for producing a realistic render.



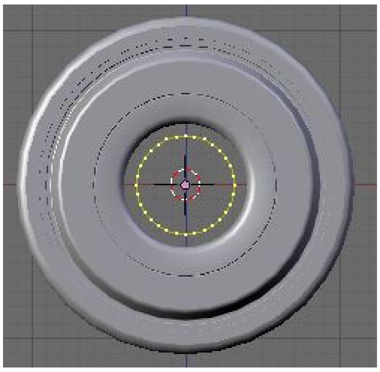
Continuing with the V-Roller assembly, in the Outliner open the eye icon for the two bearings and V-Roller. The assembly is starting to take shape but still missing a retaining nut and washer.

The nut should also impart a small amount of pre-load onto the bearing to remove any side piay. In true skateboard fashion I am going to use a 6mm nyloc-locking nut and washer.

To locate the washer and nut we only need the bearings in view, so in the Outliner close the eye icon for the V-Roller and V-RollerAxle to remove them from view.

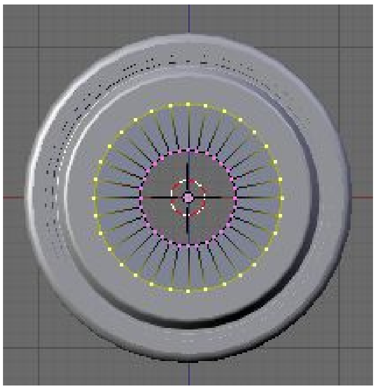


Select the left hand bearing and **Tab** into Edit Mode. **Alt-RMB** select a ring of vertices on the far left side of the bearing and snap the cursor to the centre of them. Tab back into Object Mode.



Press the **Spacebar** to open the Toolbox and select Add>Mesh>Circle. From the pop-up menu leave vertices at 32, but change Radius to 3.2 then press OK to accept. This will form the 6.4mm inside diameter of the washer.

Extrude *(Only Edges)* this vertex ring then press **Esc** to leave it in place. We will scale the extruded vertices to form the outside diameter.



The Outside diameter of the washer is 12.5mm so to find the required scale factor:

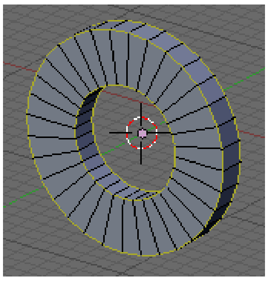
12.5 / 6.4 = 1.9531

With the extruded vertices still selected **S**cale **1.9531** to form the outside diameter.

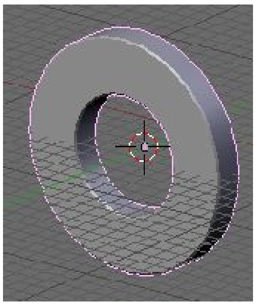
The thickness of the washer is 1.6mm so select **A**ll and **E**xtrude *(Region)* **Y -1.6**

The basic profile of the washer is formed, we now just need to add a chamfer on the corners.

Go into edge select mode and **Shift-Alt-RMB** select the two outer and two inner edges.

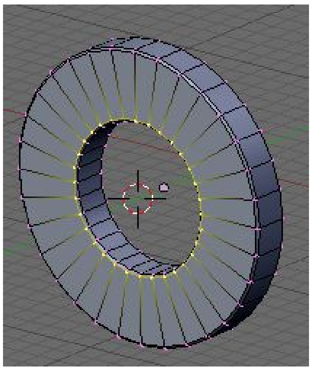


Using the Bevel Centre script and following the details given in [608 Part-4](#) add a 0.1mm chamfer. Back in vertex select mode select **A**ll and Set Smooth **W**, in the Modifiers tab add an Edge Split modifier with the default settings. If Black areas are present on the surface of the washer press **Ctrl-N** to recalculate the normals to the outside.



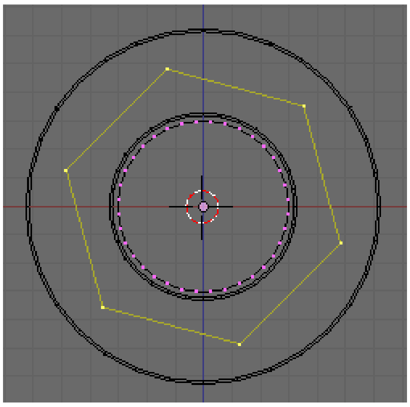
The washer is complete but before going into Object Mode we need to set the cursor ready to add the final component. **Alt-RMB** select one loop of vertices on the left hand side of the washer and snap the cursor to the centre of these. **Shift-S** Cursor>Selection.

Tab into Object Mode and in the Link and Materials panel rename the washer OB:6mmWasher.



The next thing needed is to model the M6 nut. Some consideration should be given to how many vertices to use for the nut, as the external hexagonal section will only require 6 vertices and internal circle will require more.

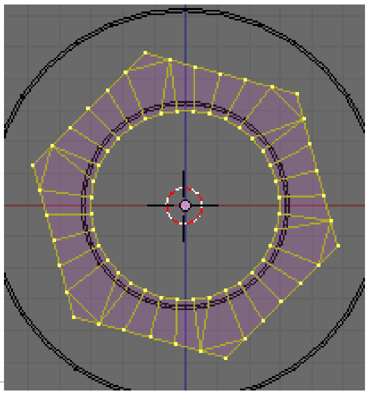
Some extra detail on the external profile will be required to form the curves on the top edge of the nut so it would simplify the modelling to keep the same number of vertices on the outer and inner diameter.



Six vertices should be enough to form the curved detail on the top of the nut so with six sides this equates to an inner circle of 36 vertices.

In front view **NumPad 1** press the **Spacebar** to open the Toolbox and add a Circle with 36 vertices and a radius of 3 Add>Mesh>Circle.

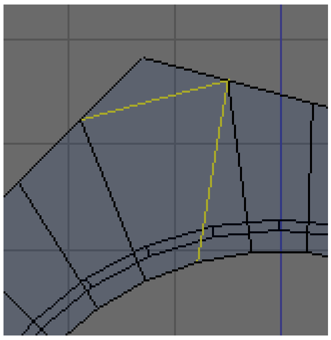
Now add a circle with 6 vertices and a radius of 5.7735 This will form a hexagon with 10mm across the flats. With the 6 outer vertices still selected, subdivide each edge of the hexagon with 5 vertices, W Subdivide Multi. Change the number in the popup menu to 5 and press OK to accept.



Select **A**ll and fill the space between both loops of vertices with faces **Shift-F**.

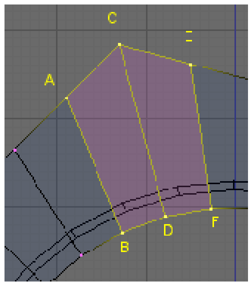
To improve the fill pattern and remove the long thin triangles press **Alt-F** (Beautify Fill). Repeat the beautify fill command several times until the internal edges no longer change.

To convert the triangular faces into quads press **Alt-J**.

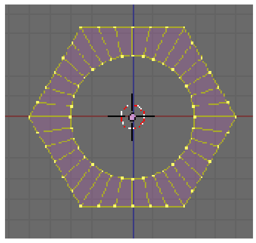


Blenders beautify fill attempts to produce triangles with the shortest possible sides and has overcompensated on the corners of the nut. If left like this the mesh would produce ugly edges when bevelled. It's worth manually rearranging these corners to form quads.

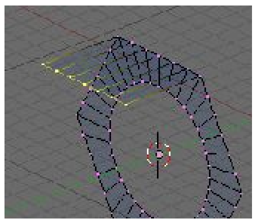
In edge select mode **Shift-RMB** select the two edges indicated and delete them **X** *(Edges).*



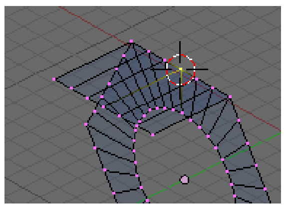
In vertex select mode select 4 vertices (A, B, C, & D) and insert a face **F**, select the next four vertices (C, D, E & F) and add the next face. The corner will now have a much better face pattern. Repeat this until all 6 corners are done.



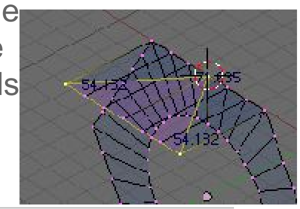
To make modelling easier we need to rotate the nut so two flats are parallel to an axis. Select **A**ll and **R**otate **-15** degrees.



To make the side faces of the nut Shift-RMB select the seven vertices of the top edge and Extrude them Y -4.

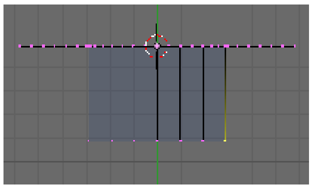


To form the radius on the top of the side face we need to spin a vertex from the faces bottom centre vertex. Select the vertex indicated and snap the cursor to it.

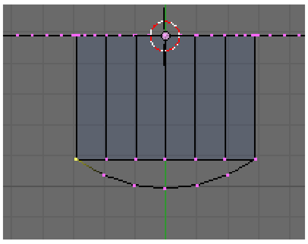


To determine the angle of the spin, with the centre vertex still selected **Shift-RMB** select the two vertices on the corner of the opposite edge and temporarily form a triangular face. With the face selected click on the Edge Angle button of the Mesh Tools 1 panel. The corner angles of the triangle will be displayed in the view. The spin angle is 71.635 degrees. Press **Ctrl-Z** to remove *(undo)* the triangle

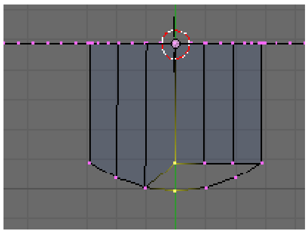
In top view NumPad 7 select the bottom right hand vertex indicated and in the Mesh Tools panel set Degr: 71.635 and Steps:6.



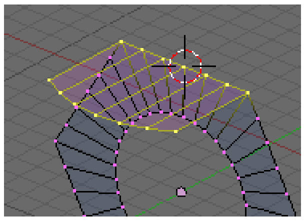
Press Spin and the ark at the top edge of the face will be formed.



Shift-RMB select two corresponding vertices and merge them together **Alt-M** at the vertex point on the ark. The selection order will determine whether you choose "at first" or "at last" from the pop-up menu.

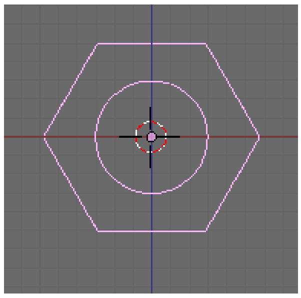


Merge the rest of the vertices on the top edge of the nut face to the ark using this method.



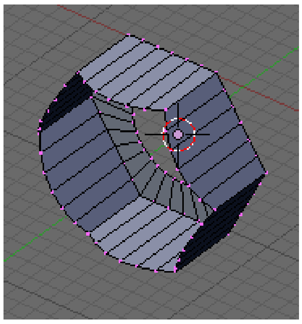
Shift-RMB select all the vertices on the side face of the nut, then Tab into Object Mode.

Snap the cursor to the object centre Shift-S Cursor>Selection. Tab back into Edit Mode.



In the Mesh Tools panel set Degr:360 and Steps:6, press Spin Dup and the other sides of the nut will be generated.

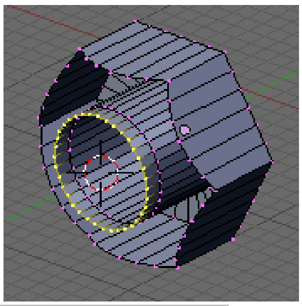
Select **A**ll and Remove Doubles **W**.

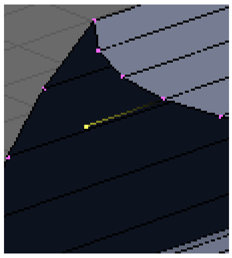


Alt-RMB select the inside diameter of the nut and **E**xtrude it on the **Y**-axis **-5**mm, then extrude it on the Y-axis a further 1mm.

Snap the cursor to the centre of the last loop of vertices.

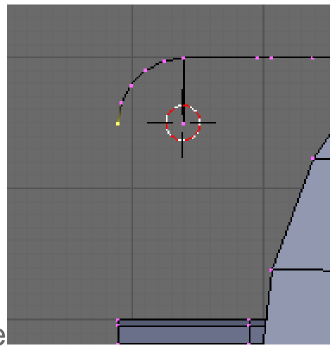
The extra loop of vertices will allow us to set a different material for the nylon insert of the nut.





Select the centre vertex of the ark on the top face of the nut and extrude it on the Y- axis.

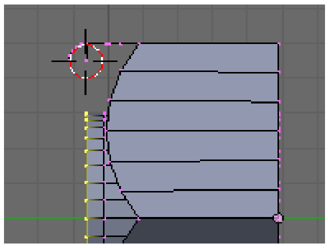
Check the Pivot Point is still set to 3D Cursor and **S**cale the vertex on the **Y**-axis to the cursor position **0**.



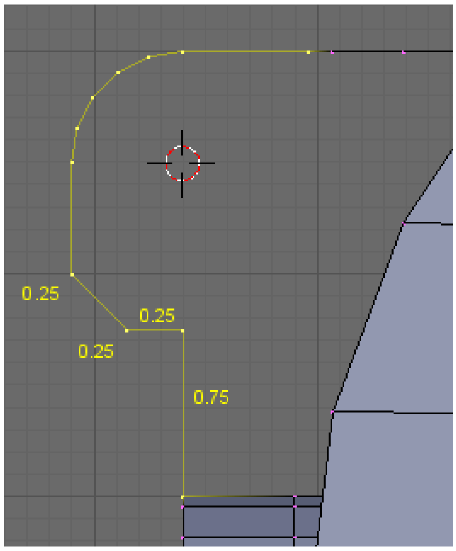
The above scale has set the vertex level to the top edge of the nut, but this edge needs a 0.5mm fillet radius. **G**rab the vertex and move it **Y 0.5**, then extrude it on the Z-axis -0.5 to set the centre of the fillet. Snap the cursor to this vertex, then select the previous vertex.

In the Mesh Tools panel set Degr:90 and Steps:5 and Spin the fillet radius.

To form the profile of the nylon insert we need to move the inside diameter back slightly.



Alt-RMB select the inside diameters top loop of vertices and move it **G** on the **Y**-axis **0.5**mm.



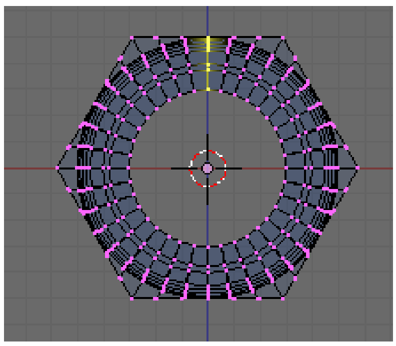
To complete the top profile of the nut extrude the top vertex of the inside diameter to the dimensions shown, constraining to the required axis and dimensional input.

Form the chamfer by **E**xtruding the vertex **Y -0.25** then **G**rabbing this vertex and moving it **Z 0.25**

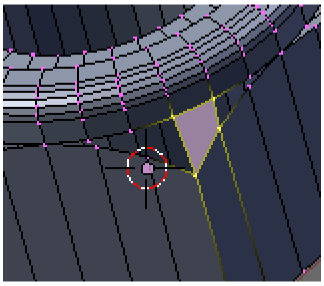
Shift-RMB select the end of the fillet radius and join it to the chamfer with an edge **F**.

Shift-RMB select the 11 vertices of the top profile.

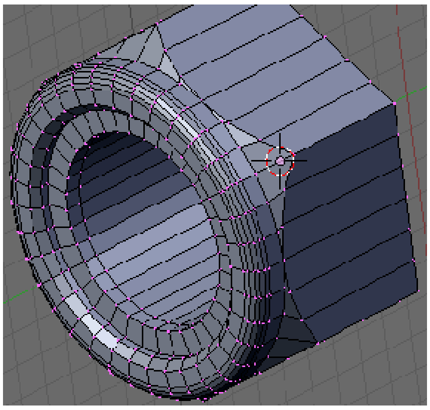
Go into front view **NumPad 1**.



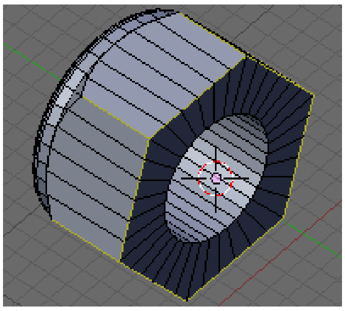
In the Mesh Tools panel set Degr:360 and Steps:36 and Spin the top profile.



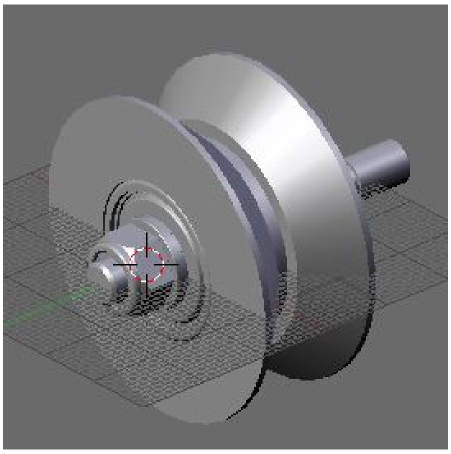
We are now left with a series of breaks in the mesh between the top profile and nut sides. To keep the mesh organised its best to manually fill these areas.



Select 4 vertices *(3 on the corners of the openings)* corresponding to where a face should be and press **F** to insert a face. Continue around the perimeter of the nut until all faces are filled.



In Edge Select mode **Alt-RMB** select the bottom edge of the nut, then **Shift-RMB** select the 6 corner edges. We will add a 0.1mm chamfer to these using the Bevel Centre script described in 608 Part-4.



To finish add an Edge Split modifier, but because the edge angles are 30 degrees the same as the default settings for the modifier, ugly shading patterns will be created on the corners of the nut. Change the angle setting to 29 degrees to overcome this problem.

In the Link and Materials panel change the name to M6NylocNut

Tab into object mode and in the Outliner bring the other objects into view.

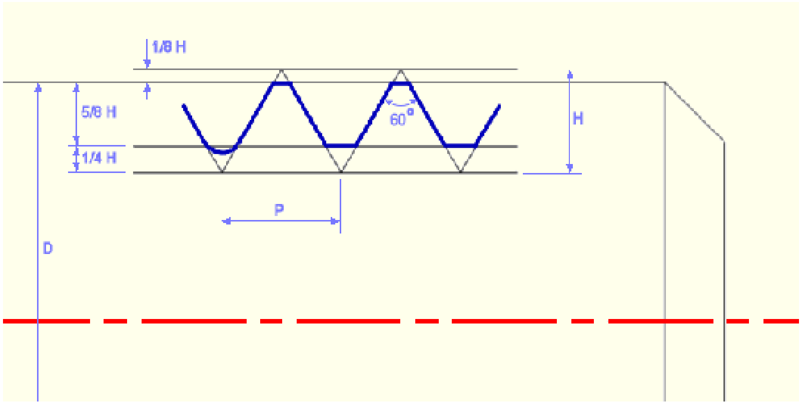
Save your work **Ctrl-W**.

I hope you have found this a worthwhile exercise. The intention was to demonstrate how components can be modelled together in assemblies using one component to help set the location and surface geometry of the next, using Blenders Snap tools to accurately locate the new Object.

Part 3 will detail how to use Blenders Screw tool to generate a thread profile

Before we can model the thread we need to understand the thread form. ISO Metric threads come with a Standard profile and as the V-Roller axle will use an M6 thread, I will describe the set-up of this size.

Layout of a Metric Thread



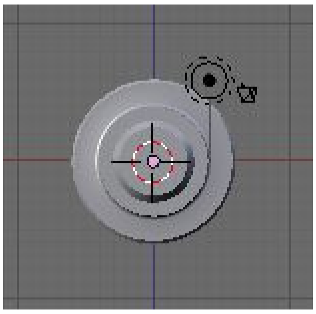
Key:

D	Major Diameter
P	Pitch
H	Thread Height

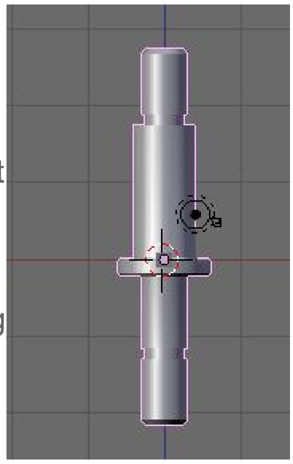
The ISO Metric thread profile is a fairly simple shape to construct in Blender and with the screw tool only one instance of the thread profile is required. As a model engineer I am not going to discuss thread tolerances or fits in any detail. You should however be aware that the finished male thread profile (bolt) should be kept below the bold blue line of the diagram above and the finished female thread profile should be kept above the bold blue line, otherwise the two won't fit together. If you need them tolerance classes are defined in ISO 965-1.

For this exercise we will make the thread to the nominal profile above. To construct the thread only two pieces of information are required the Major Diameter and the Pitch. A few of the more common sizes are detailed in the table below.

Major Diameter	3	4	5	6	8	10	12	16
Pitch	0.5	0.7	0.8	1	1.25	1.5	1.75	2

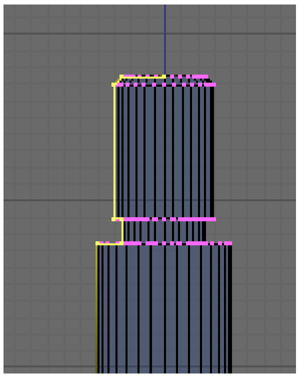


We will build the thread around the V-Roller axle. Open a new Blender project and go into front view **NumPad 1**. Append the V-RollerAxle into the scene **Shift-F1** navigate to V-Roller.blend and select Object>V-RollerAxle. The axle will appear facing you in the front view.



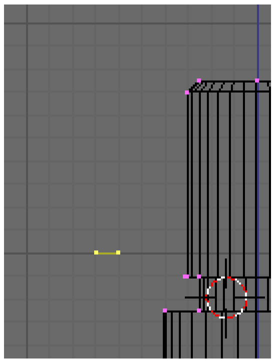
The screw tool spins a profile around the Z-axis so the profile needs to be created and the screw operation performed in front view. The Axle needs to be rotated so it is vertical in the front view. **R**otate **X -90**.

Tab into edit mode and **Shift-RMB** select the 7 vertices making up the left-hand profile of the threaded section.



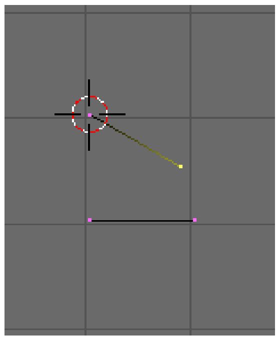
Copy these vertices **Shift-D** then **Esc** to leave them in place. Separate the copied vertices from the Object **P**. Its easier to work on the separated profile rather than the complete axle.

Tab into Object Mode and select the profile. **Tab** back into Edit Mode.



We now need to work out the Thread height. It could be done with trigonometry given that the pitch is 1mm and the thread angle is 60 degrees. But I find it easier to do in Blender.

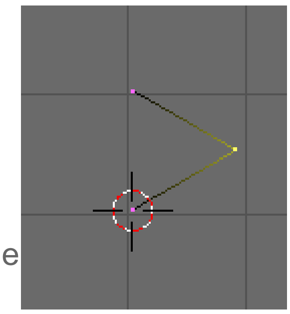
De-select **A**ll vertices then to the left of the axle **Ctrl-LMB** click to add a new vertex. **E**xtrude this vertex on the **X**-axis **1**mm. The thread form is an equilateral triangle so the sides of the thread triangle will be the same length as the pitch.



Link select both vertices of the edge and copy them **Shift-D** on the **Z**-axis **1**mm (the thread pitch).

Select the top left vertex of the two edges and snap the cursor to it **Shift-s** Cursor>selection.

Then select the vertex on the other end of the edge and with the Pivot set to 3D Cursor **R**otate it **30** degrees.

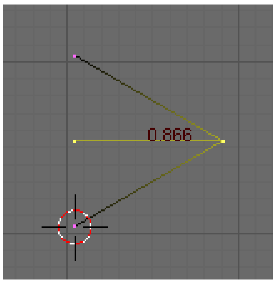


Snap the cursor to the bottom left vertex and Rotate this -30 degrees.

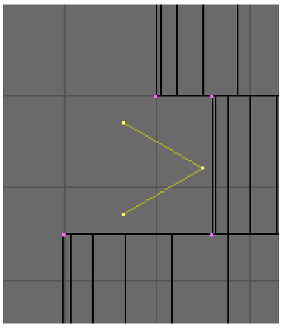
Select **A**ll and remove doubles **W**.

Select the centre vertex and **E**xtrude it on the **X**-axis then scale it to the cursor **S**cale **X 0**.

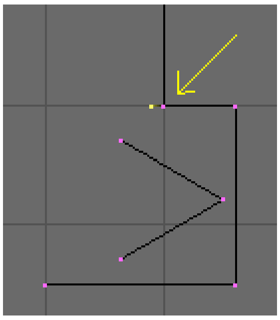
In the Mesh Tools 1 panel press Edge Length and select the centre edge. The Edge Length shown is the Thread Height.



Delete **X** the vertex on the left-hand side of the central edge. Select the three vertices of the thread profile and move **G** them towards the undercut at the bottom of the thread.

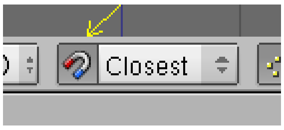


If you haven't already got one open split the 3D view and open the [Outliner](). Click the eye icon for the axle to remove it from view.

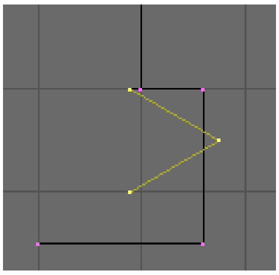


Select the vertex on the major diameter of the thread and **E**xtrude it on the **X**-axis **-0.108**mm (1/8 H)

We can now use the snap tool to position the thread V profile.



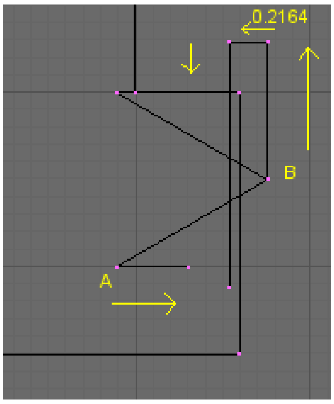
Click on the magnet Icon on the view header. Select the 3 vertices of the V and move them **G**, whilst moving hold down **Ctrl** and move the cursor towards the end vertex. The V will snap into position.



We now need to add reference geometry to allow us to cut new vertices on the major and minor diameters.

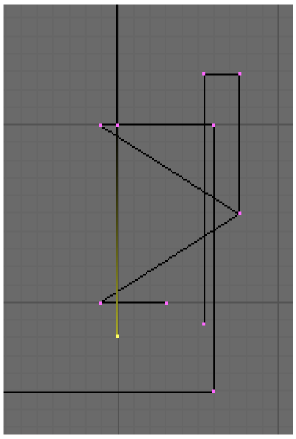
Extrude vertex A on the **X**-axis

Extrude vertex B on the **Z**-axis as detailed, then **E**xtrude this **X**

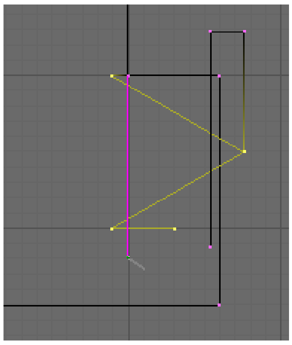


-0.216mm (1/4 H) then **E**xtrude again on the **-Z**-axis ensuring the edge crosses the V.

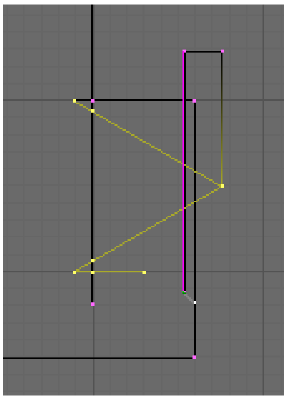
To finish the reference edges, extrude a vertex from the major diameter across the v.



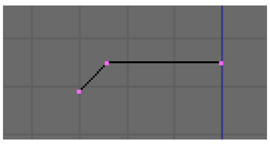
Select the three vertices of the V and cut **K**nife (Exact), snapping the cut **Ctrl-LMB** to the vertices of the major diameter.

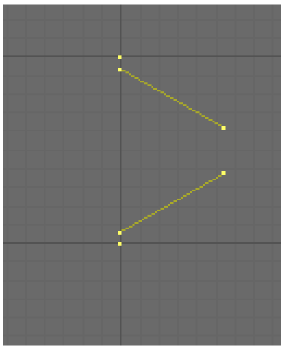


Repeat the cut snapping the knife to the vertices of the minor diameter.



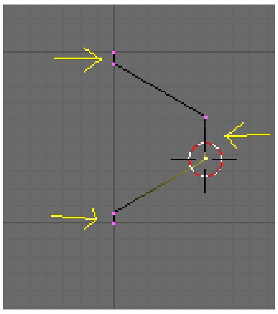
Delete the reference vertices, but ensure the top chamfered edge of the thread is not deleted, as this will be used to locate the cursor when we spin the thread.



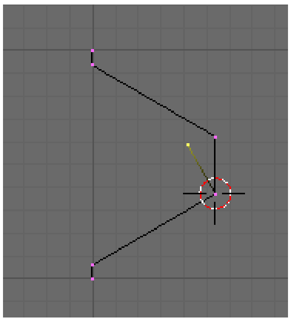


Add Edges **F** to the vertices of the major and minor diameter. Threads usually have a radius at the root of the thread so we will add a fillet.

Select the vertex at the bottom of the minor diameter and snap the cursor to it **Shift-S** Cursor>Selection.

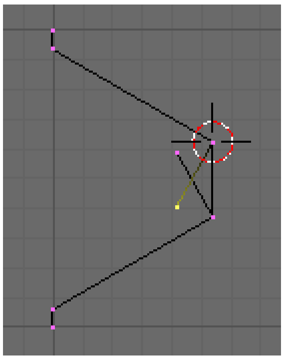


Shift-RMB Select both vertices of the minor diameter and copy them **Shift-D**, then **Esc** to leave them in place. With the Pivot in 3D Cursor **R**otate the edge **-30** degrees.

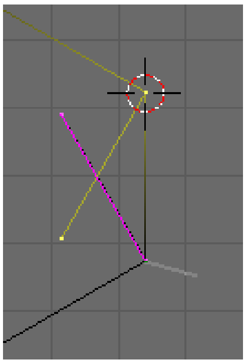


Select the vertex at the top of the minor diameter and snap the cursor to it **Shift-S** Cursor>Selection.

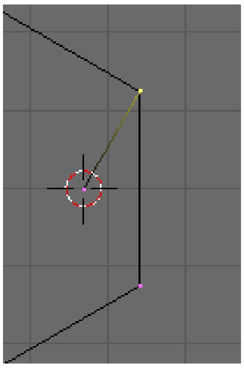
Again **Shift-RMB** Select both vertices of the minor diameter and copy them **Shift-D**, then **Esc** to leave them in place. This time **R**otate the edge **30** degrees.



Where the two edges cross is the centre point for the bottom fillet. Cut a vertex on the intersect **K**nife (Exact) and using **Ctrl-LMB** to snap the cut to the rotated edge.

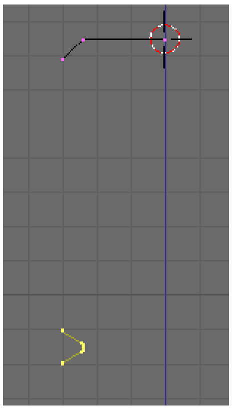


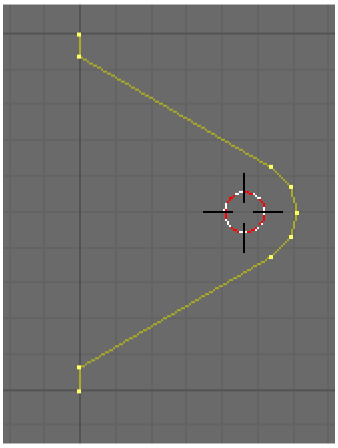
Snap the cursor to the intersect and Delete the reference vertices.



Select the vertex at the top of the major diameter and in the Mesh Tools panel set Degr:120 and Steps:4 Press Spin and the profile for one pitch of the thread will be created.

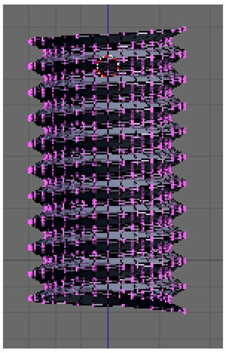
Select **A**ll and Remove Doubles **W**.
Select the vertex on the thread centreline (right hand vertex on the top chamfer profile) and snap the cursor to it.





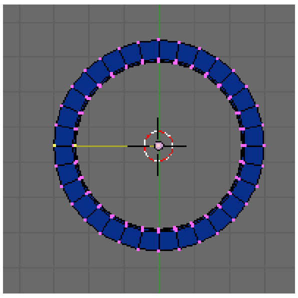
De-select **A**ll vertices, then **L**ink select the thread profile.

We need the thread to continue past the chamfer so we can later combine the chamfer detail to the thread. Counting the grid squares we will need 10 turns.



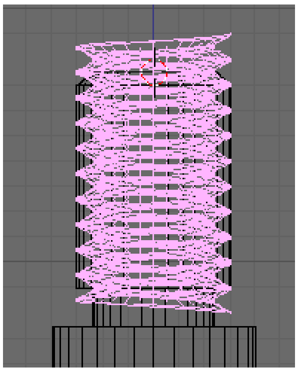
In the Mesh Tools panel set Degr: 360 Steps:32 and Turns:10 Make Sure Clockwise is not selected.

Press Screw and the thread will be formed.

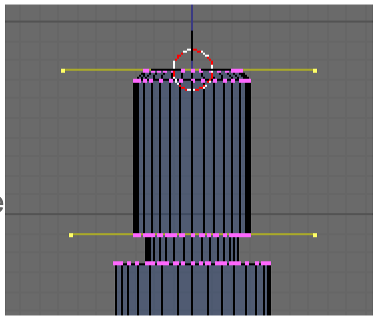


Go into top view **NumPad 7**. De-select **A**ll then **L**ink select the centre and chamfer vertices. Delete these **X**.

Select **A**ll and Remove Doubles **W**.

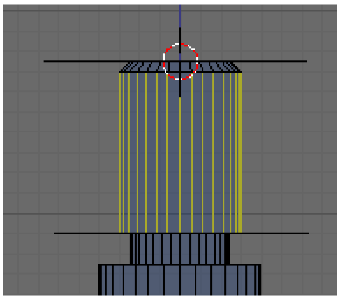


Tab into Object Mode and in the Outliner open the eye icon for the axle, bringing it back into view. If necessary move the thread in the Z-axis to align with the axle. Close the eye for the thread.

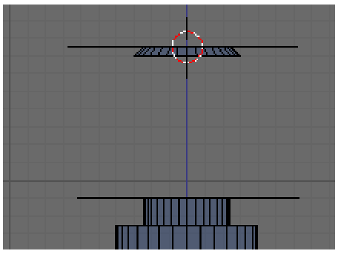


We now need to prepare the axle to accept the thread.

Go back into front view and select the axle. **Tab** into Edit Mode and select the top right vertex of the chamfer and copy it **Shift-D** moving it to the right of the axle on the **X**-axis. **E**xtrude this vertex on the **X**-axis to the left of the axle. Repeat this on the bottom vertex loop of the thread section.

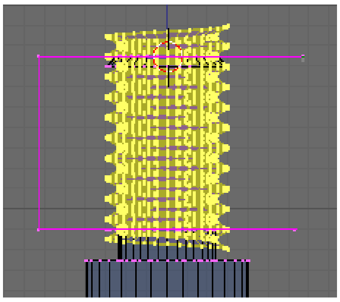


Go into edge select mode and paint a selection **B B** across the straight section of the thread.



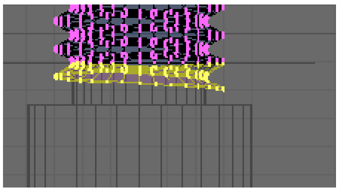
Delete these **X** *(edges).*

Go back into vertex select mode.

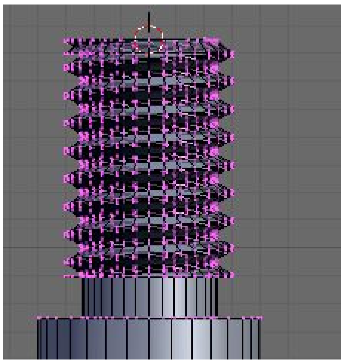


Tab into Object Mode and in the Outliner bring the thread back into view. **RMB** select the thread then **Shift-RMB** select the axle. Press **Ctrl-J** to join them into one mesh.

Tab into Edit Mode and De-select **A**ll then **L**ink select the thread. With the Knife tool, cut two rows of vertices across the thread, **K**nife (Exact) and snapped **Ctrl-LMB** to the reference edges.

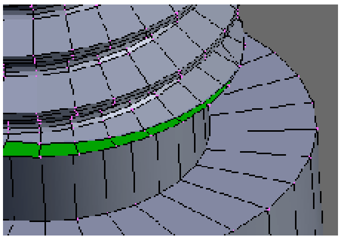


De-select **A**ll then **B**ox select the vertices below the bottom reference edge. Zoom in **MW** to make sure all the vertices below the edge are selected *(not the vertices on the edge)* Delete these vertices **X**.

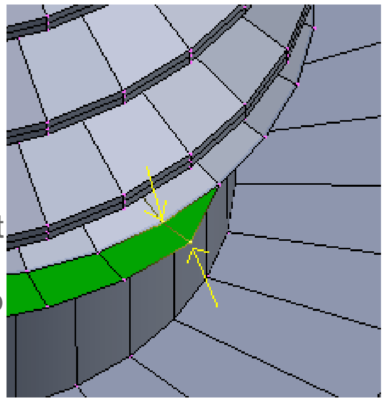


Box select the vertices above the top reference edge and delete these. Select the two reference edges and delete them.

The thread is now the correct length for the axle but there is still more to do. We must join the base of the thread to the under-cut and the top of the thread to the chamfer.



If you zoom in on the base of the thread you will see the flange that was originally on the axle sticking out past the edge of the thread (highlighted in green).

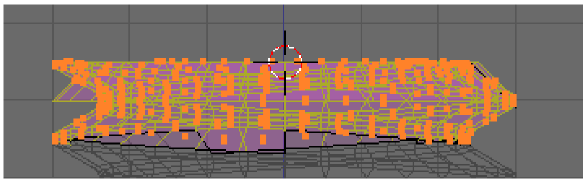


To correct this we need to manually merge the vertices of the original axle flange onto the corresponding vertex of the thread.

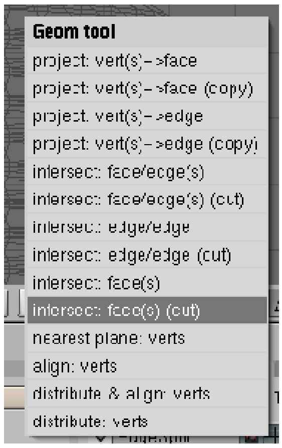
RMB Select a vertex on the flange then Shift-RMB select the corresponding vertex on the thread. Press Alt-M to merge the vertices and choose "At Last" from the pop-up menu.

Repeat this around the circumference of the axle.

The intersect between the top chamfer and the thread is a much more complicated detail. Because the intersect doesn't occur on a set plane there are no vertices on the line of intersection. Therefore we cannot simply merge vertices to obtain the correct profile. The first part of combining the thread and chamfer will be to create a line of vertices on the intersect between the two sets of faces.

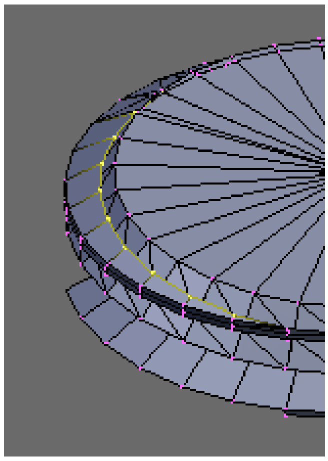


Go into face select mode and box select the top section of thread and chamfer. Press **Shift-H** to hide all the other vertices.



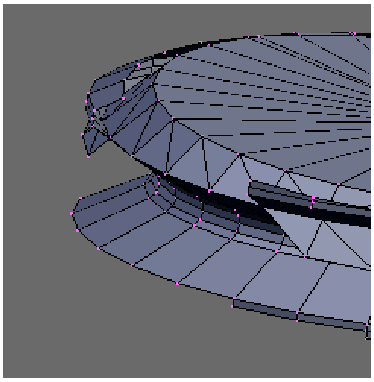
We can now use another of the python scripts to cut the vertices on the intersect of the faces. Split the 3D view and open a Script Window (detailed description in 608-4). With all the faces still selected, in the Script window click on Scripts>Mesh>Geom Tool and from the popup menu click on "intersect: face(s) (cut)". A new loop of vertices will be created on the intersect between the faces. Go back into vertex select mode, select **A**ll and Remove Doubles **W**.

The Geom Tool script isn't bundled with Blender but can be downloaded from the Blender Website.
http://wiki.blender.org/index.php/Scripts/Catalog
A description for loading the script is also available from this page.



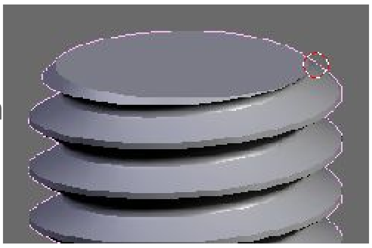
With the new edge created on the intersect its now simply a matter of deleting the vertices, edges or faces that are not required. It sounds simple but this will test your patience and call on many of the editing techniques you have learned.

Only delete **X** a few vertices at a time, if necessary **Ctrl-Z** will undo the change. In places you may need to merge vertices **Alt-M** and other places you will need to add new faces **F**. Its also worth noting on one side of the axle the thread intersects the chamfer in two places.

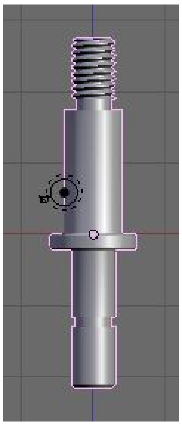


As a new user this may take a fair amount of time, but as your experience grows this will only take a few minutes and the end result is well worth the effort.

Once complete press **Alt-H** to bring back all the hidden vertices. Select **A**ll, Remove Doubles **W** and Set Smooth **W**.

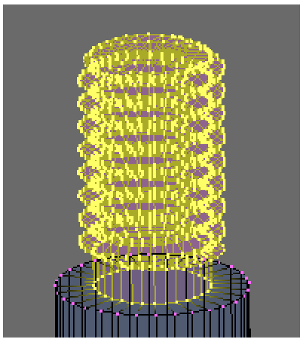


That completes the top thread. Rather than repeating all that work on the bottom thread we can simply copy the top one and reposition the copy to complete the axle.



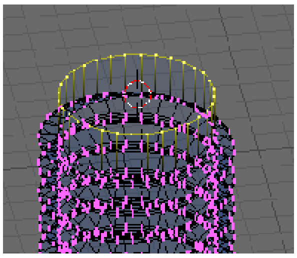
In front view **B**ox select the thread vertices, then loop select **Shift-Alt-RMB** the inner loop of vertices on the undercut next to the main body of the axle.

Copy these Shift-D and move them to the side.

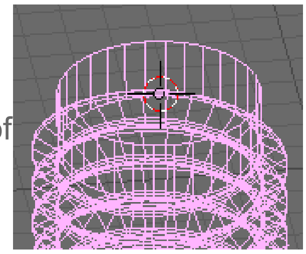


In front view **R**otate the copied vertices **180** degrees.

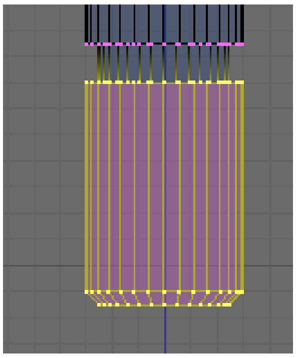
Separate the copied thread from the axle **P**. **Tab** into Object Mode, Select the copied thread and then **Tab** back into Edit Mode.



Select the top row of vertices and snap the cursor to them **Shift-S** Cursor>Selection.

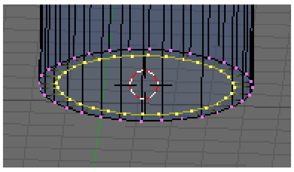


Tab into Object mode and in the Mesh panel click the Centre Cursor button. This will move the object centre to the centre of the top row of vertices.



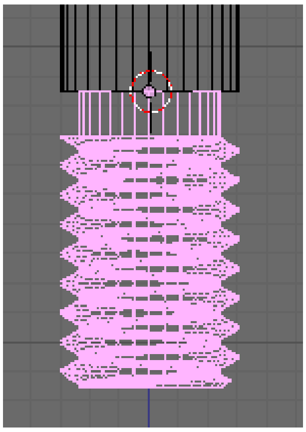
Select the axle and delete the vertices of the bottom thread.

Alt-RMB select the inner loop of vertices where the under cut was.



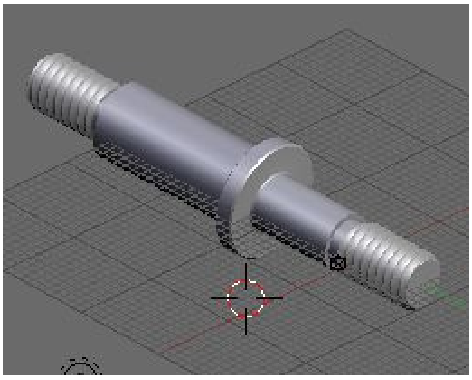
Snap the cursor to the centre of these vertices.

Tab back into Object Mode and select the thread.



Snap the thread to the cursor **Shift-S** Selection> Cursor.

With the thread still selected **Shift-RMB** select the axle and joine the two objects into one **Ctrl-J**.



Tab back into Edit Mode, select **A**ll and Remove Doubles **W**. to complete the axle.

This axle will have 7274 vertices, compared to 1418 vertices of the axle without the detailed thread.

You may also want to set up a camera and lights and render an image of the shaft as detailed in 608-9.

Tab into Object Mode and save your work.

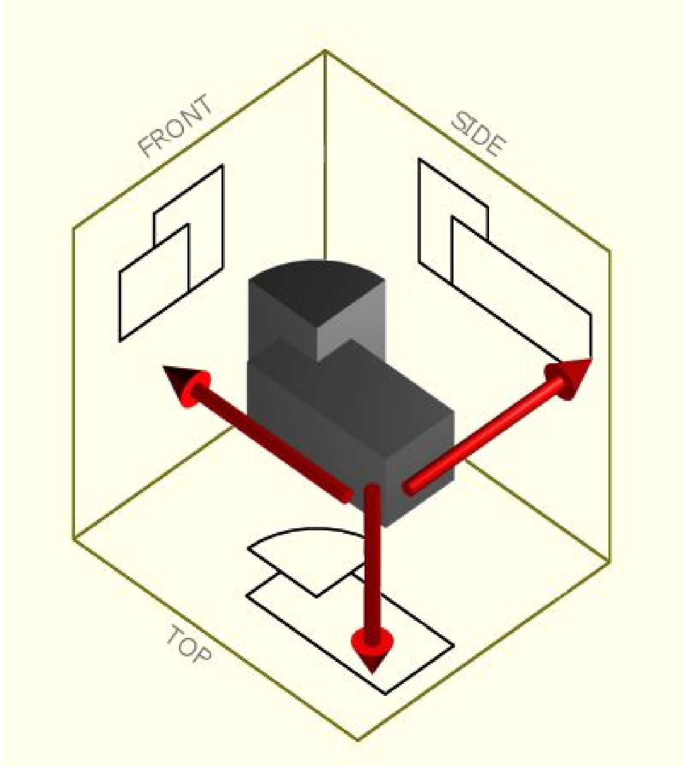
In the next section we will do a dimensioned drawing of the V-Roller components.

Most of the techniques necessary to layout an orthographic drawing were covered in Part 11 of the 608 Bearing Tutorial so rather than just repeating what's in that section this will be just a brief description of the layout process.

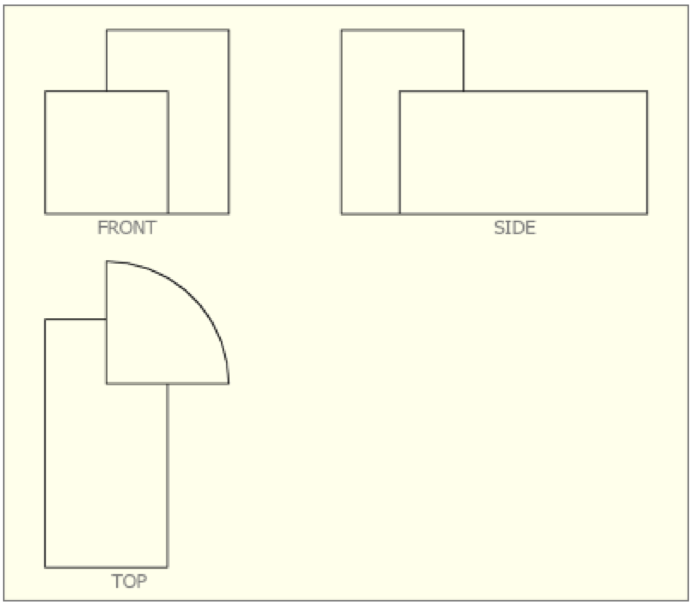
Initially though I thought it would be good to mention the two standard methods of laying out a drawing. 1st Angle Projection and 3rd Angle Projection. To see how the views are represented on paper it's easier to fold the paper into a cube around the component and project the view onto the cube. When the cube is unfolded it gives the correct layout.

1st Angle Projection

In First Angle projection the view is projected through the component, so the front view is projected onto the back wall and the top view is projected onto the base.

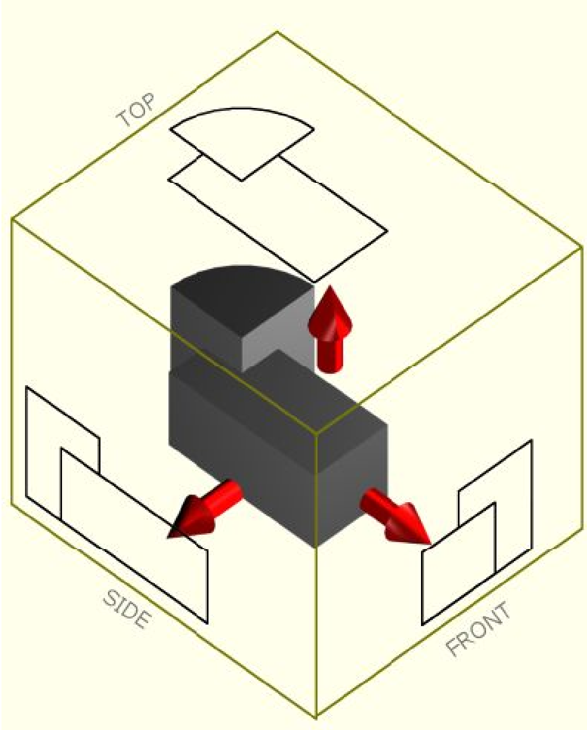


When the 1st Angle view is folded out the front view is at the back of the top view and the side view is on the opposite side of the front view. This type of layout often causes confusion with people who aren't completely familiar with orthographic layouts.

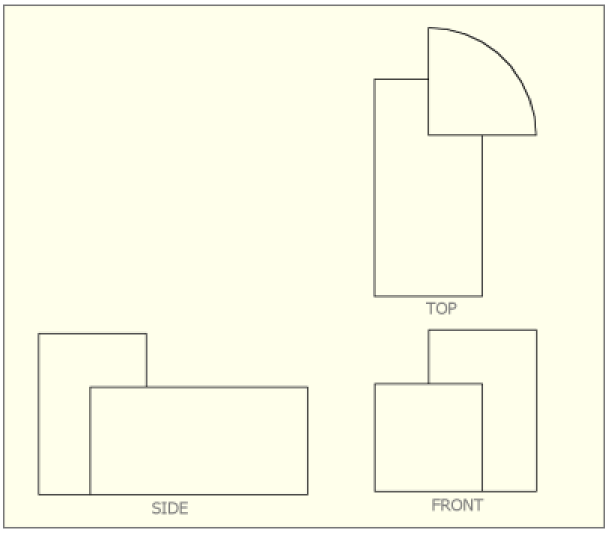


3rd Angle Projection

In 3rd Angle projection the side facing the cube is projected onto the cube, so the top view is on the top of the box and the front view is on the front of the box.

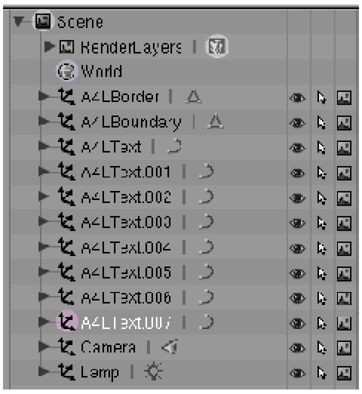


In 3rd angle projection the views are positioned on the same side of the view next to them, so the top view is on top of the front view and the side view is on the side of the front view that it represents. This is a much easier layout to understand and my preferred choice.



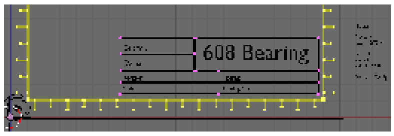
Hopefully that,s enough for you to appreciate the formal aspects of orthographic layouts, Its a subject where you can go into ever increasing detail and this is just a brief primer to get you started. If you want to learn more about layouts there is a lot of detail on www.technologystudent.com, it's worth a visit as it contains a lot of in depth advice.

I think that's enough on layouts so let's get back to Blender. In part 10 we created a page Layout for an A4 Portrait Page. We can start by importing this and then rotating the border to form an A4 Landscape layout. Start a new Blender project. If you already have Blender open save your work **Ctrl-W** then press **Ctrl-X** to open a new file. Delete the Cube Object that opens with each new project **X**, as we don't need it.



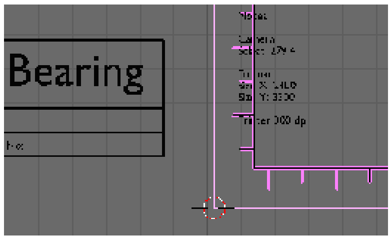
Append all the A4p objects from the PageTemplate.blend file created in the 608-Bearing tutorial. **Shift-F1** to open the File Browser window in Append mode and from the "PageTemplate.blend" file **LMB** click Object then **RMB** select all the A4p objects. Click on Load Library to bring them into the new file. They will be placed on Layer one, as this was the layer they were created on. Go into front view to see the layout **NumPad 1**.

In the outliner select the A4pBorder object then in the Link and Materials panel change its name from A4p (portrait) to A4L (Landscape). Repeat this for all the other A4p Objects.



It's now time to rotate the border. The only problem is that the Title box is part of the Border mesh so we first need to separate the Title Box from the Border. Either in the Outliner or 3D view select the A4LBorder Object and **Tab** into Edit Mode. Select **A**ll vertices, it's easier to deselect the vertices of the title box than select the vertices of the Border.

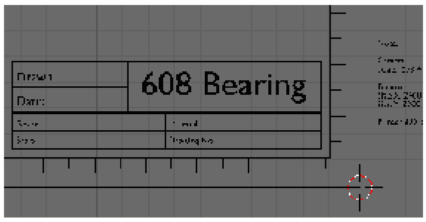
To de-select the vertices of the title box press **B** for box select, but this time drag a selection box over the vertices you need to de-select using the **RMB**. The vertices will no longer be selected. On the 3D View Header press select>>Inverse, this will invert the selection so the title box is now selected and the Border isn't. *(You could have just de-selected all then box selected the Title Box, but I wanted to show the Box Deselect feature!)*



With the Title Box vertices selected press **P** (part) to separate them from the current mesh and choose "Selection" from the pop-up menu.

Tab back into Object Mode and select A4LBoundary, **Tab** back into Edit Mode and select **RMB** the bottom Right Hand vertex snap the Cursor onto this **Shift-S** Cursor>Selection.

Tab into Object Mode and **RMB** select the A4LBorder Object and Shift-RMB select the A4LBoundary Object. In the 3D View Header set the Pivot point to 3D Cursor, then **R**otate the Border and Boundary **90** degrees.

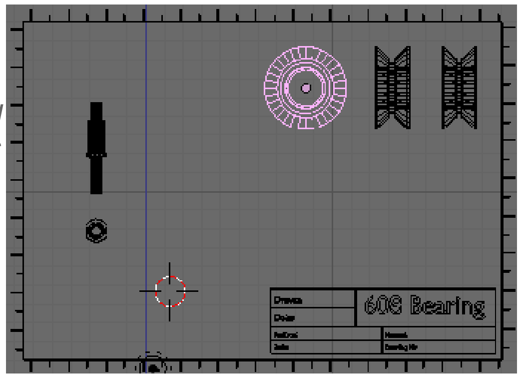


The Border is now disjointed from the Title Box so **G**rab the Border and move it on the **X**-axis until the bottom Right Hand corner sits around the Title Box.

The final thing to do is amend the Camera and output Format settings detailed in A4LText.007 so Size X becomes 3300 and Size Y becomes 2400.

You now have an A4 Landscape page template that can be appended back into the PageTemplate.blend file.

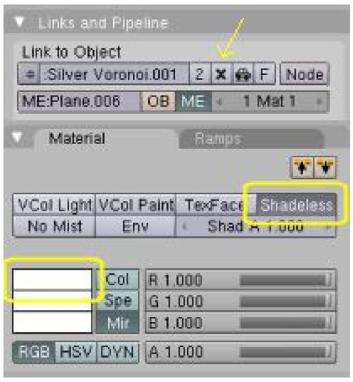
Append the V-Roller Object from V-Roller.blend onto the scene and position it within the Border. *(If it doesn't appear on the view after appending check the Eye icon in the Outliner is open or it's layer is active)* Copy this **Shift-D** and move it on the **X**-axis to the right of the original. **R**otate the copied V-Roller on the **Z**-axis **90** degrees. Copy the rotated V-Roller and position this to the right of the original. We will use the second copy to form a sectioned view.



Append the V-RollerAxle from the same file and position this within the border. Copy this on the Z-axis and position it above the original. *(3rd Angle projection Top view sits above Front View)*

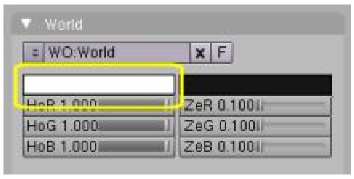
Save the file as V-RollerLayout.blend

We now need to change the material for all the components. Select the 1st V-Roller and In the Links and Pipeline tab of the Material Buttons press the X to remove its material, then click Add New to add a new material.



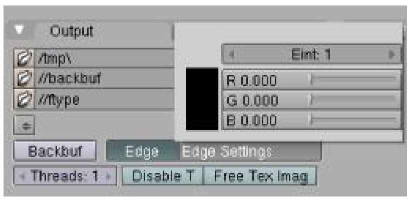
In the Materials tab set the colour to white and click Shadeless so it renders as a pure white colour.

In the World Settings change the Background to white.

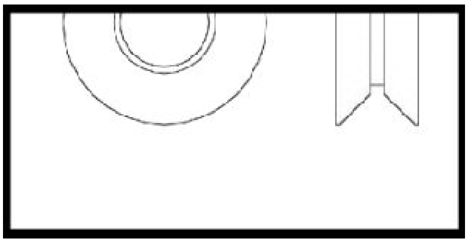


With the material set on the first V-Roller **Shift-RMB** select all the other components, then **Shift-RMB** select the 1st V-Roller to make it the active object. Press **Ctrl-L** (Make Links) and select Materials from the popup menu. This will copy the material from the active object onto all the other selected objects.

In the Output tab of the Scene Buttons click Edge to allow the Edge filter to draw an outline around the components and then click on Edge Settings and set Eint (Edge Intensity) to 1 to give lines only on the most prominent edges.

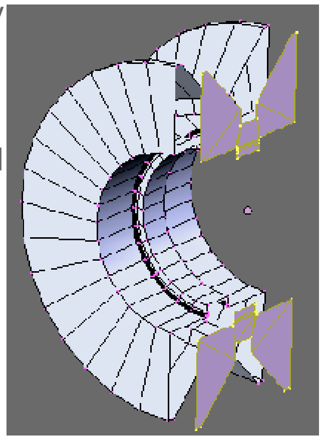


In the Format tab change size X to 3300 and Sixe Y to 2400. Select the camera, go into camera view **NumPad 0** and align the camera with the Boundary Object. Set the Camera to Orthographic in the scene buttons Camera tab



Because we are working with such a large output size you can select areas of the camera view to do a test render. In the camera view press **Shift-B** and drag a selection box over the area you would like to test. The render will then be confined to the area of the selection.

To come out of Border render de-select Border in the Render tab.



In side view **NumPad 3** cut the right hand V-Roller in half by deleting all the vertices forward of the centreline. This is easier carried out in local view NumPad **/**.

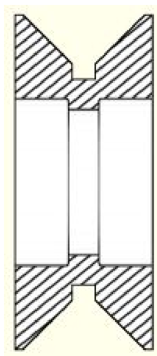
Alt-Shift-RMB select the vertices on the two open ends and copy **Shift-D** them forward of the 1/2 V-Roller on the **Y**-axis. **Shift-F** fill these faces, beautify the fill **Alt-F** and convert to Quads **Alt-J**. The faces have been separated from the V-Roller to allow the edge filter to detect the edges cleanly.

With the vertices of the disconnected faces still selected we need to add an image texture with a hatch pattern. If you haven't already got one available use one of the textures from the 608-Bearing tutorial [Part 11.](#)

In the Link and Materials tab of the Editing Buttons click New to add a second material to the mesh and then press Assign to assign the second material to the selected vertices.

In the Shading Buttons, Texture sub context add a new image texture and load your hatch pattern.

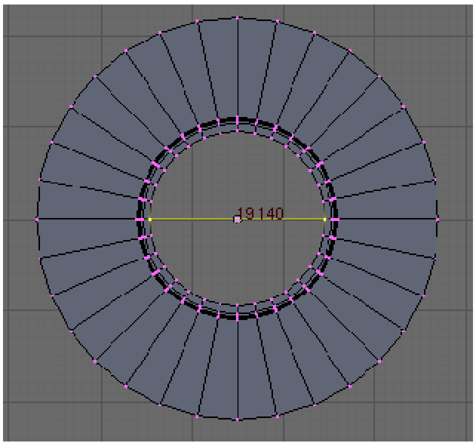
If you need more detail of how to do this go back to the 608-Bearing tutorial, [Part 11](#) describes the process in detail.



Because Image textures are stretched to fit the object's bounding box size the hatch will have been skewed vertically so increase Y repeat to 2 or 3 in the Map Image tab of the texture buttons. This will repeat the texture 2 or 3 times in the Y-axis.

If you do a test render you should end up with something like the image opposite.

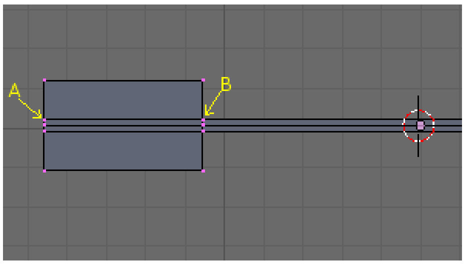
Radial Dimensions



To construct a diameter dimension select a vertex either side of the horizontal centreline and add an edge **F**. Click on Edge Length in the Mesh Tools 1 tab of the Editing Context buttons. We can use this figure for the dimension text.

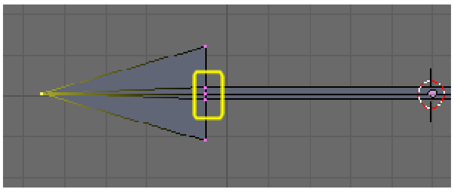
Separate this edge from the V-Roller **P,** choose "Selected" from the pop-up menu. **Tab** into Object Mode and select the new edge, which will be used to form the dimension line. Go into Local view **NumPad /** for dimension line, then **Tab** into Edit Mode *(Note I have removed the material to make the images clearer for this tutorial).*

Select both vertices and **E**xtrude them **Z 0.1**. Select the bottom two vertices and **E**xtrude these **Z -0.1** This adds thickness to the dimension line.



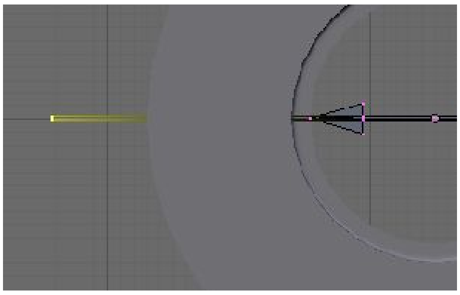
Select **A**ll and cut **K** through the horizontal edges choosing Knife (Multicut) from the pop-up menu and accepting the default 2 cut's.

Select the six new vertices that have been cut and **S**cale them along the horizontal edges **X** until they are around 4mm from the ends of the dimension line. Select the two vertices A & B and Extrude them in the Z axis 1mm Repeat this on the other three edges. You should end up with a dimension line that has a box on either end.



Select the five left hand vertices and with the Pivot Point set to Median Point **S**cale the vertices to **0** then Remove Doubles **W**. You will end up with an arrow shaped end.

Repeat this on the other end of the dimension line.



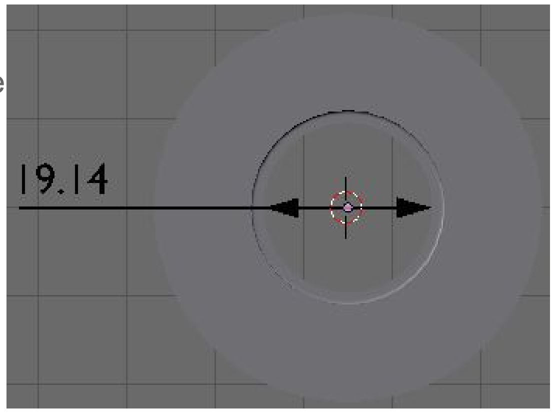
The next requirement is to add a leader line for the dimension text. Select the three vertices in the yellow box opposite.

Toggle back into Global View **NumPad /** and extrude these vertices on the **X**-axis out past the edge of the component.

Add the Black shadeless material from the border to the dimension line.

Tab into Object Mode and in side view **NumPad 3** move the dimension line in front of the V-Roller. With the dimension line selected snap the cursor **Shift-S** to its object centre Cursor>Selection.

Insert a Text object and in the Editing buttons Font tab, increase its size to suit the page scale (4 on my layout)



Backspace through "Text" to remove it, then add the dimension size using the number keys on the main keyboard *(not the NumPad keys)*

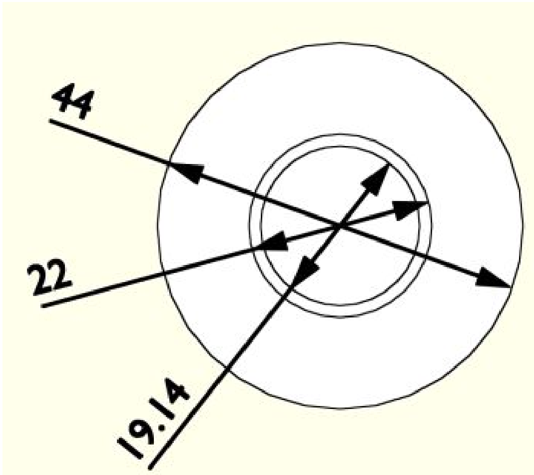
Tab into Object Mode and move **G** the text over the leader line.

Finally add the Black material to the text object.

With the cursor snapped to the Object centre copy the the dimension line and text, then rotate the copy from the horizontal.

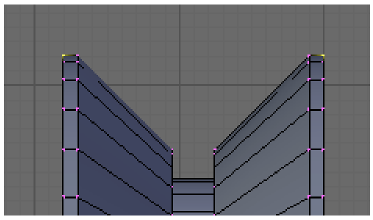
The original dimension line can now be modified by moving the arrows on the X-axis to a new diameter.

This technique can also be used for radius dimensions by cutting the dimension line on the centre-point and deleting all the vertices to one side of the cut.

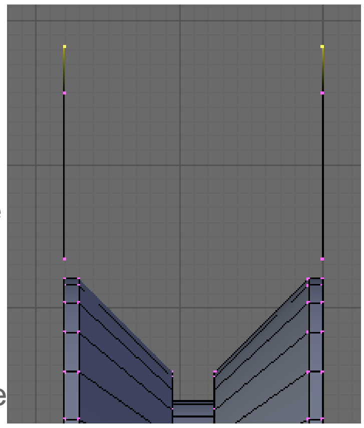


If you haven't been doing so it's worth frequently saving your work. Press **Ctrl-W** and save the file.

Linear dimensions



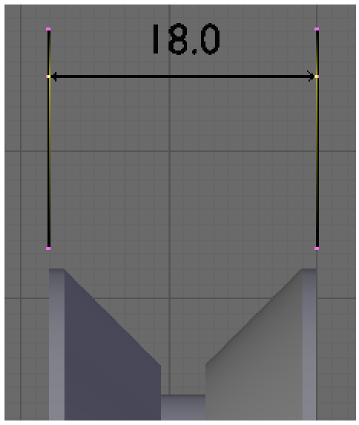
Linear dimensions using the Blender Caliper script were covered in detail in the 608-Bearing tutorial Part 11 along with scaled views. If you can't remember how to add the dimensions please revisit Part 11.



As a quick refresher, in Edit Mode select the two vertices where you want the dimension measurement to be taken from.

Copy the vertices and move them away from the model *(constrained to an axis)*. This gives a break between the extension line and the model. Extrude these vertices to the point where you want the dimension line, then extrude again past this point.

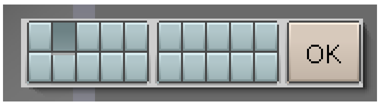
To thicken each edge so it will show on the render, select the three vertices of one edge and extrude it away from the other edge 0.2mm. Do the same with the other edge.



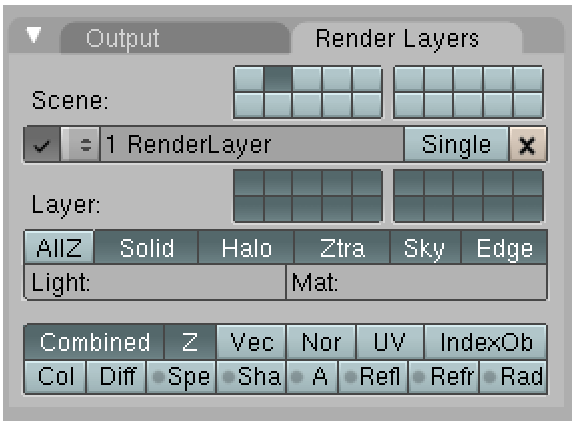
To add the dimension select the two vertices on the inner edge of the extension lines. Open Blender Caliper, adjust the measurement settings for the dimension line and press measure. (You may need to play with the settings to get a suitable font size and dimension line scale).

Select the vertices of the extension lines and separate them from the models mesh **P**. Go into Object Mode and join the extension lines to the dimension line created by Blender Caliper by selecting both objects and pressing **Ctrl-J.**

As you progress through your layout join all the dimension and extension lines into one object. It helps to change the colour of the dimensions to help differentiate them from the model.

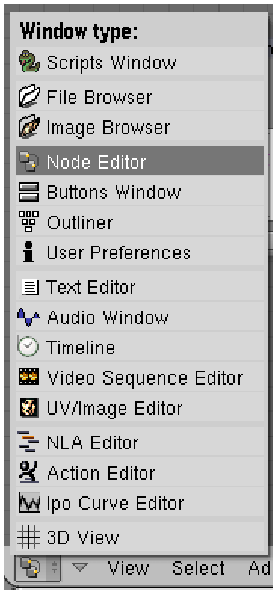


The models are going to be rendered using the edge settings so need to be rendered separately to the drawing border and dimensions. Select all the models and move them onto layer 2 **M**ove then click the second layer box in the pop-up.



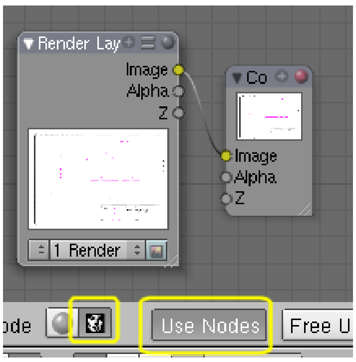
In the Render Layer tab of the scene buttons select layer 2 to limit the render to this layer. In the Output tab make sure Edge is still selected.

In the Format tab select PNG as the file format and check the RGBA button. Render the line drawings of the components. When you save the render it will save the component layout onto a transparent background. Save **F3** the drawing as V-RollerLayout1.png



To combine this drawing with the border and dimensions, we can use the Node Editor. The Node editor is a complex image editor and needs a book of its own to describe its full capabilities. I will just touch on what's needed to combine the two layers.

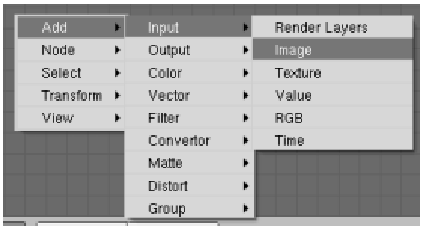
In the render Layers tab select layer 1. In the Output tab deselect Edge to turn off the edge filter. Render the layer and close the render window.



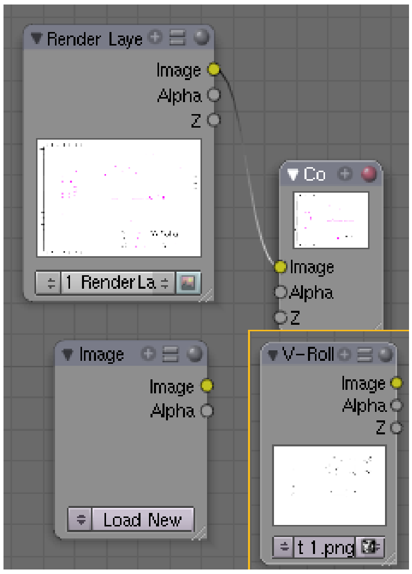
In the 3D View click the window type button and choose Node Editor. On the Node Editor Header click on the face icon to select composite nodes, then click Use Nodes. A Render Layer Node and Composite node will appear in the view joined with a curved line.

The nodes will have a thumbnail view of the Border and Dimensions. We now need to add an input node so we can load the image with the line drawings.

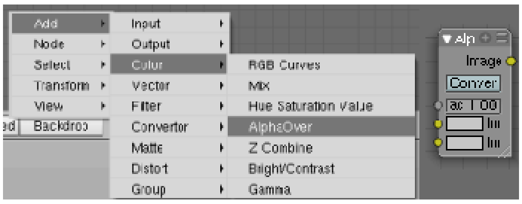
Press the **SpaceBar** to open the node menu choose Add>Input>Image, a new node will appear in the View. You can move the nodes around by **LMB** dragging the Header at the top of the node. Position the Input Node below the Render Layer Node.



Press Load New and load the drawing V-RollerLayout1.png. The thumbnail of the image will appear in the node. Nodes are arranged with inputs on the left-hand side and outputs on the right-hand side.



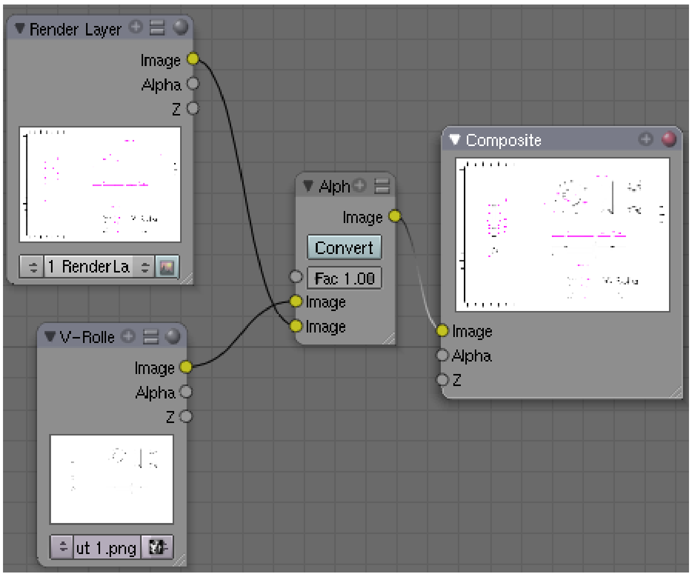
We now need to add a node that can combine both the Render Layer and Image nodes together. To do this press the **SpaceBar** and choose Add>Color>AlphaOver. The AlphaOver node will be placed in the view.



We need to re-wire the nodes to give us the correct output.

LMB click and drag the cursor across the link between the Render Layer Node and the Composite Node. This will cut the connection.

LMB click and hold on the yellow output socket on the Render Layer node and drag the mouse to the bottom yellow input socket on the Alpha Over node. A new connection will be made.

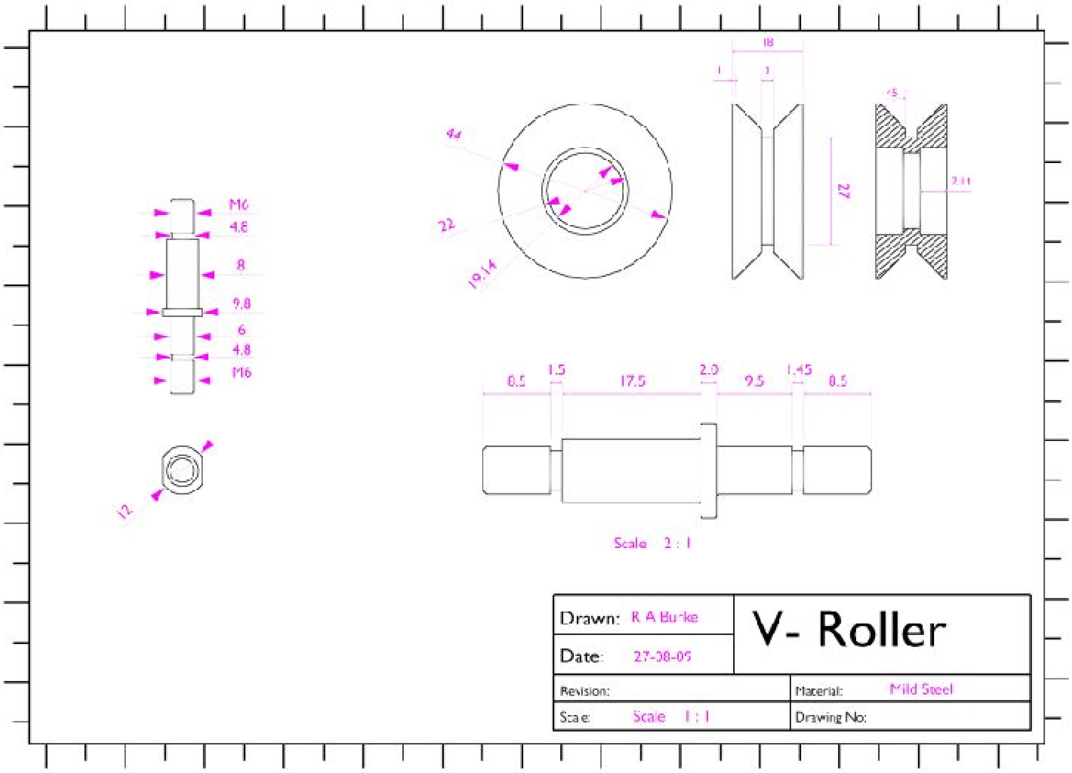


In the same way connect the output of the image node to the top input of the Alpha Over node. Then connect the Output socket of the Alpha Over node to theinput socket of the Composite node. The connections are now complete.

Before rendering the layout you must tell Blender to use the composite output. In the Scene buttons Anim tab click Do Composite, then render the layout.

If all has gone well you will get a composite layout with a dimensioned line drawing of the components. In the Scene buttons Format tab Click RGB as we no longer need alpha in the image and Save the Layout drawing **F3**. Save your file **Ctrl-W**.

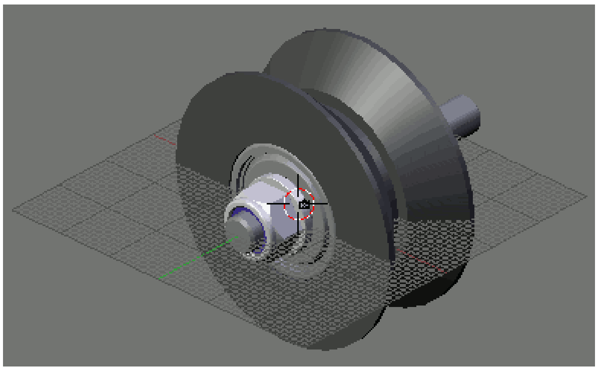
The final thing necessary to print the drawing to scale, is to adjust the pixels per inch to 300 in an image-editing program such as Gimp or PhotoShop.



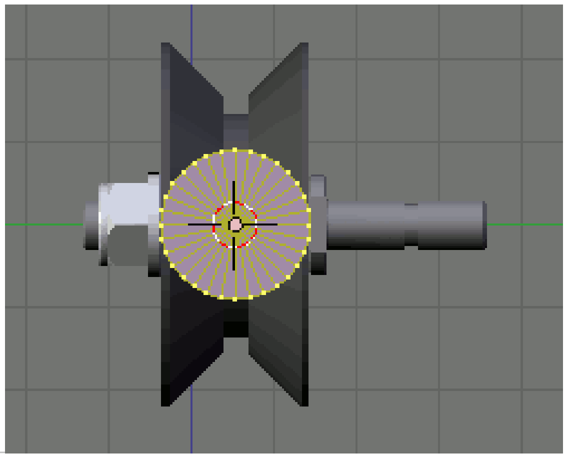
By now you should be fairly familiar with Blenders modelling capabilities. The 608 Bearing and V-roller tutorials have covered most of the commonly used tools and techniques, so this won't be so much of a tutorial as a discussion on the steps needed to use Blender as a tool to help you design a casting. As the next stage of my CNC router upgrade is to redesign the X-axis slides I will use this as the motive for designing the casting. We will again reuse the bearing and V-roller as the building blocks for the casting layout.

There are many casting techniques that could be used for this component such as sand casting, die-casting and centrifugal casting, but because of my limited workshop facilities and the availability of a pottery kiln, I have chosen to use the investment casting technique. This is where a wax model of the part is fabricated then dipped into a refractory slurry which is dried, the wax is melted out leaving the refractory casing which when fired becomes the mould for the molten aluminium. The mould is then broken away from the aluminium when it has cooled.

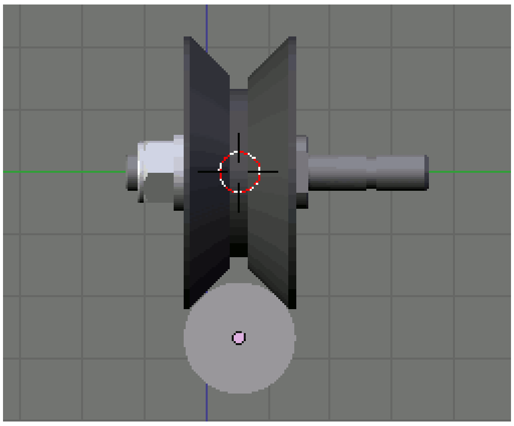
The benefit of this method is you can produce an accurate wax model without worrying too much about withdrawal tapers or undercuts, If you can make the component in wax you should be able to produce an investment mould from it. I will go into a little more detail about the mould making and casting process in the foundry section. Here I will concentrate on using Blenders modelling capabilities to design the casting.



If you haven't already got blender running this is the time to start it up? Delete the default cube **X** and then append into the scene **Shift F1** the V-Roller, bearings, shaft, nut and washer assembly created in the V-Roller tutorial. They will be placed into the scene rotated so the roller will run along the X-axis. Go into side view **NumPad 3** as we need to add a shaft for the V-Roller to run along. To make sure the shaft is centred to the V-Roller, select the V-roller and in the Edit Buttons click "Centre New" this will ensure the object centre is on the centre of the V-Roller. We can now snap the cursor to the V-Rollers object centre **Shift-S** Cursor>Selection.

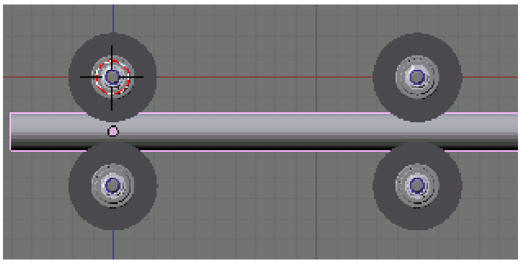


Add a cylinder to represent the shaft **SpaceBar** Add>Mesh>cylinder and in the pop-up menu set Vertices: 32, Radius: 9, Depth: 100. In its current position the shaft penetrates through the V-Roller so we need to move it down so that the shaft sits below the 'V'.

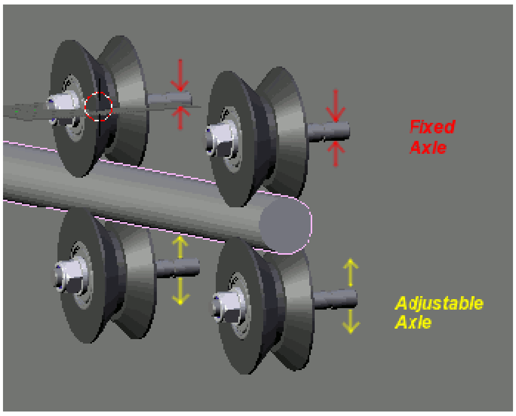


Tab into Object Mode then **G**rab the shaft and move it on the **Z**-axis until it sits just below the V-Roller. Zoom in fully and repeat this if necessary to get the closest possible alignment. You can also zoom into a selection box by pressing **Shift-B** and dragging a selection box over the zoom area you require.

In front view **NumPad 1**, **Tab** into Edit mode and **B**ox select the right-hand vertices. Move these vertices **G** along the **X**-axis **300**mm. This will make the shaft 400mm long. **Tab** back into Object Mode.

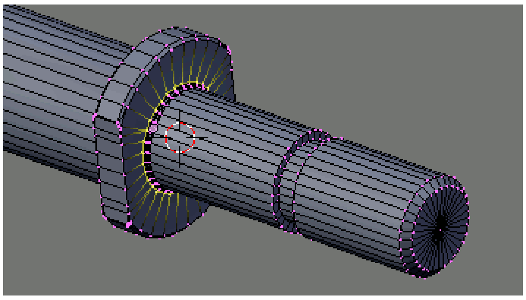


It's possible to have the V-Roller rigidly aligned to the X-axis using just 3 rollers, as I am going to reuse this set-up on other areas of the machine I am going to use 4 rollers. In front view **NumPad 1**, **B**ox select the V-Roller assembly and copy it **Shift D**. Move it along the **X**-axis **150**mm. Now **B**ox select both V-Roller assemblies and copy them **Shift-D**, moving the copies on the **Z**-axis until the 'V' is below the shaft. In side view **NumPad 3** Zoom in close to position them as accurately as possible



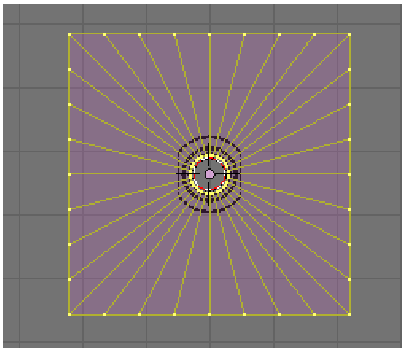
Its not feasible in a home workshop to make components to micron accuracy so some form of adjustment will be necessary to position the V-Rollers tight to the shaft. I am going to fix the top two rollers into the main casting, but allow the bottom rollers to be adjusted on the Z-axis. For this I will use a simple rebated block with elongated bolt holes. This can simply be located within a rebate in the main casting.

The Adjuster Block

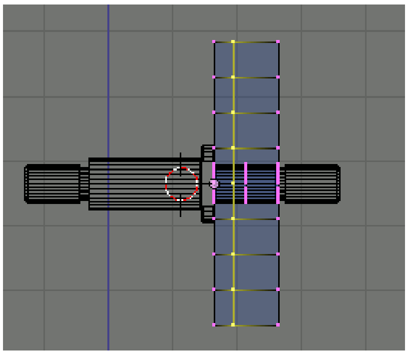


To make the adjustable block, RMB select the bottom right hand V-Roller axle and go into Local View **NumPad /**. Select **Shift-Alt-RMB** the loop of vertices at the back of the fillet and snap the cursor to the centre of them, **Shift-S** Cursor>Selection. This gives us the location point for the adjuster. Go into Object Mode and in front view Insert a mesh circle, **SpaceBar** Add>Mesh>Circle, in the pop-up menu set Vertices: 32. and Radius: 3.

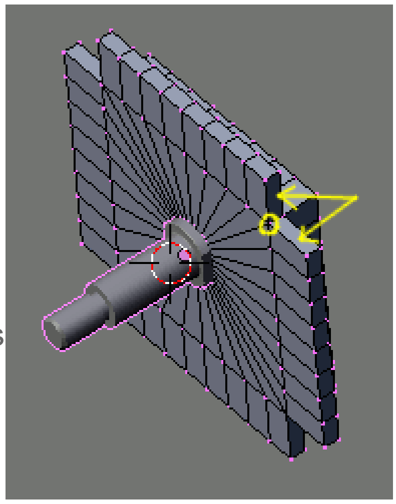
Whilst still in Edit Mode add a Plane and **S**cale it by a factor of **22** to give a 44mm square. Delete the face from the plane **X** "Only Faces" then subdivide the edges 7 times. **W** "Subdivide Multi" and set **7** in the popup menu. This will give our outer square the same number of vertices as the inner circle. Add faces between the inner circle and outer square by pressing **F** and selecting "Skin Faces/Edge Loops". Select all and **E**xtrude "Region" along the **Y**-axis **10**mm, to add thickness to the component.



In order for the adjuster block to be able to be positioned in the casting it needs some side flanges that will also incorporate the elongated bolt holes. In side view **NumPad 3** cut a loop of vertices **K** "Midpoint". **G**rab the new loop of vertices and move them on the **Y**-axis **-2**mm, this will give us a 3mm face to form the flange from.



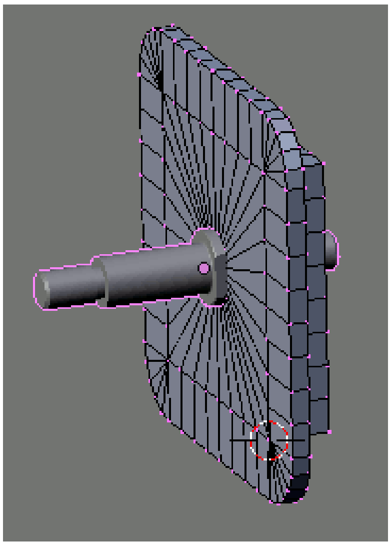
Select the flange face's, one side at a time and extrude them 10mm. The top and bottom flange will shield the components of the slide from dust produced by the router.



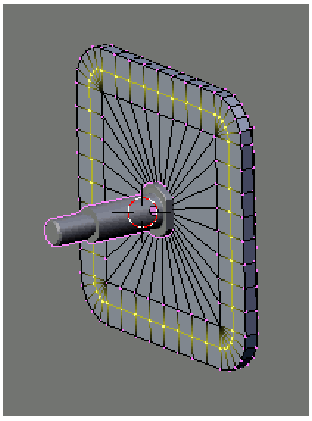
Delete the two corner faces indicated, **X** "Faces" on each of the corners. Make sure the edge between the two faces is also deleted.

Select the vertex indicated and snap the cursor to it. **Shift-S** Cursor>Selection. Then select the four vertices from one of the deleted faces.

In front view spin a corner radius with five vertices.

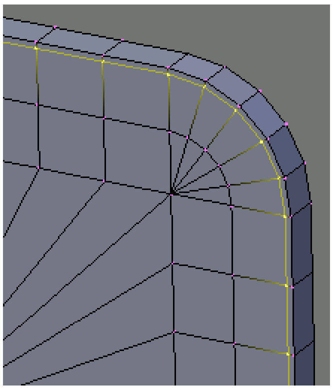


When all the four corners have been spun Select **A**ll and remove doubles **W**.

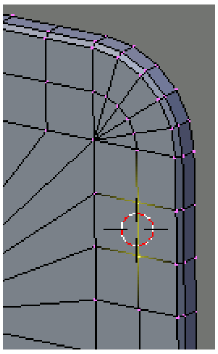


We now need the centre line of the flange to position the elongated bolt holes. It can't be loop cut because the corner faces are triangles.

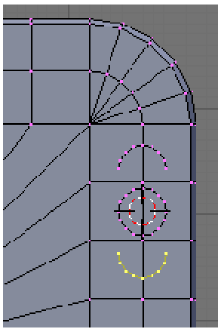
Use the Knife tool (Midpoints) and cut the loop indicated.



To add a chamfer to the edge of the adjuster loop cut **Ctrl-R** the outer loop of faces. With the Edge Length button activated, slide these to 0.5mm from the edge. Do this on the front and back of the flange.
Now select the front outer edge loop and move it 0.5mm on the Y-axis. Do the same on the back outer edge but move this -0.5mm.

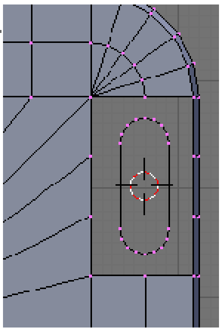


Snap the cursor to the middle of the two vertices shown.



In front view add a circle, Vertices: 16, Radius: 2.2 (clearance for a 4mm bolt).

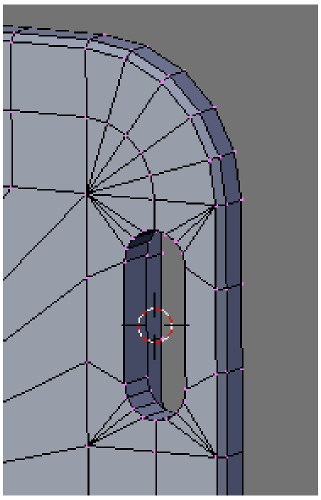
Copy the vertices from the circles centreline and above and move the copy 4mm on the Z-axis. Then copy the vertices of the circle from the centreline and below moving them -4mm on the Z-axis.



Delete the original circle and the flange vertices closest to it.

This leaves you with the outline of the slot positioned centrally on the flange.

Alt-RMB select the vertices of the elongated hole, then **Shift-Alt-RMB** select the vertices of the flange that surround it. **Shift-F** to fill the area with faces. **Alt-F** to beautify the fill and **Alt-J** to convert to quads.

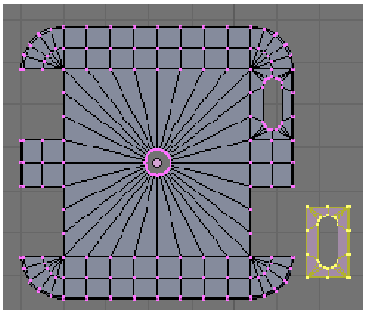


Copy the new faces and move them 3mm on the Y-axis.

Shift-Alt-RMB select the two elongated slots and loft faces between them **F** "Skin Face/Edge Loops".

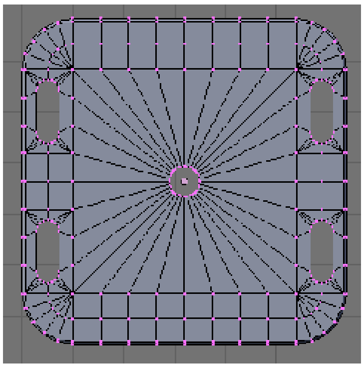
Select all and remove doubles.

Select the vertices central to where the other three slots are required and delete them. Copy the slot faces and surrounding faces. and use Blenders snap tools to snap the copy to the other locations.



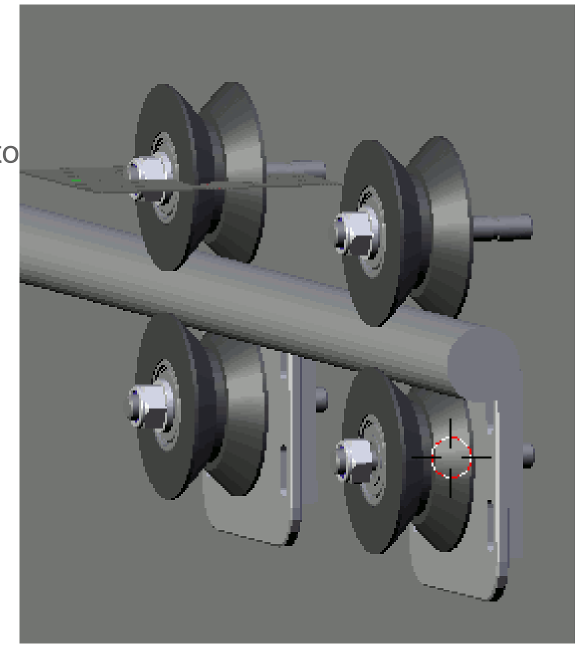
First Rotating the two left-hand copies 180 degrees.

Finally select all and remove doubles to complete the adjuster.



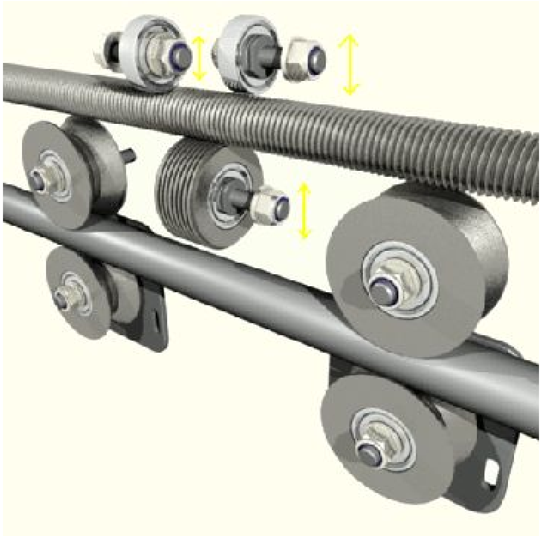
Once the flange is complete go back into Global view **NumPad /** and copy the adjuster to the other V-Roller

Shift-D X -150



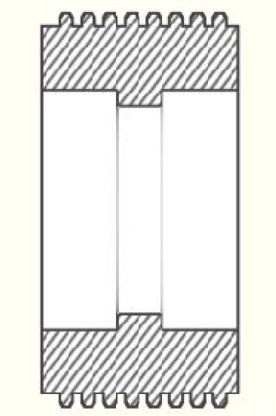
The Lead Screw & Roller-nut

WE have now got the locations for the fixed rollers and the adjuster blocks. A few other components are needed on the casting because it will also hold the lead screw roller-nut.



I am using an M16 threaded rod as the lead screw and have designed a simple roller-nut based on the V-Roller and axle. It's simply a series of slots at 2mm pitch to marry in to the M16 thread.

To stop the lead screw from flexing away from the nut a couple of bearings will be located above the lead screw and offset slightly to either side of the centreline. These bearings will use a shortened version of the V-Roller axle.

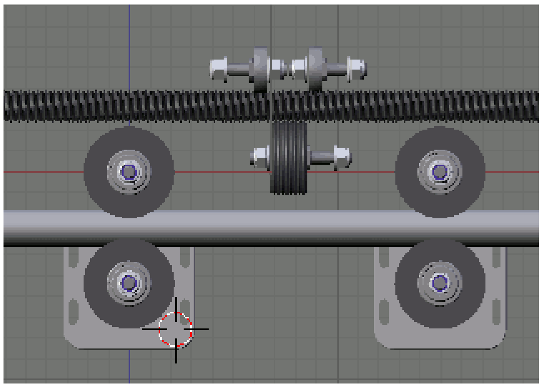


The roller-nut and bearings will also need to be adjustable, so the brackets that hold them back to the main casting will also need to allow some movement in the Z-axis.

My CNC machine is configured with two X-axis slides, one either side of the table. The Y-axis runs between them forming a bridge type layout. The X-axis therefore also has to locate the mounting points for the Y-axis. If you have a look at the photos of my old machine on the [CNC page]() at [www.rab3d.com]() this will make more sense.

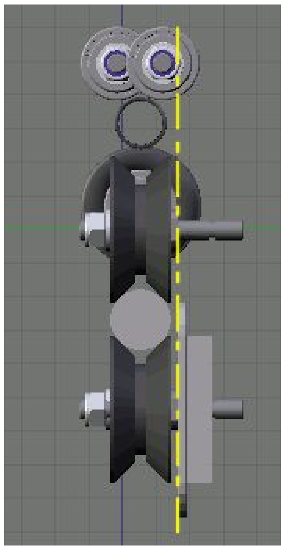
At this stage of the design, things are very flexible, none of the component positions are fixed and it's easy to move things around to optimise their location.

We have now accounted for all the parts of the X-axis, so in part-2, I will start constructing the main casting around them.



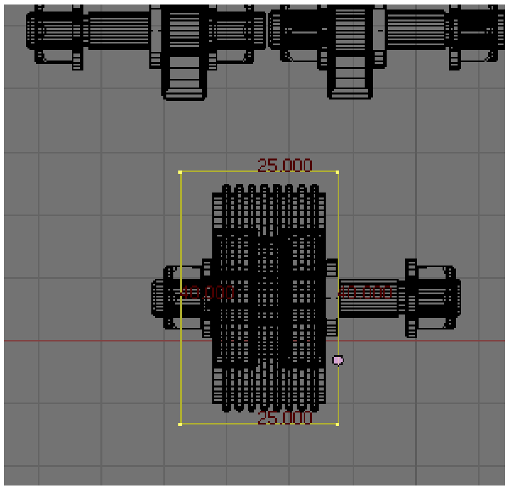
We now have all the components needed for the X-axis roughly positioned. So it's time to put a little thought into what shape the casting needs to be to accommodate the components.

In front view the components are fairly spread out and could possibly be moved closer to the centre to reduce the footprint of the X-axis.



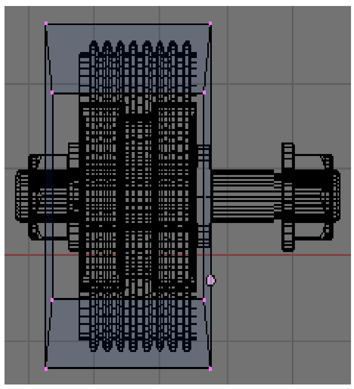
In side view its clear that some of the components will penetrate the front mounting face of the casting. It will be necessary to provide a recess behind the roller nut and top right hand bearing.

The size and location of the recesses will determine how close the other components can be to the centre of the casting.



The first part of the casting to model is the recess behind the Roller-nut. To make modelling easier you can hide the slide shaft and lead screw by clicking the eye icon in the Outliner. Select an adjuster block and in Edit mode snap the cursor to the front face of one of the adjuster blocks. Tab into Object mode and in front view add a plane. In object mode move the plane central to the Roller nut and resize it so it is larger than the nut. One side should be aligned with the back of the axle flange.

Delete X Only Faces to remove the face from the plane

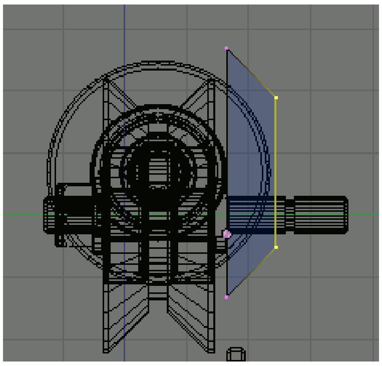


Extrude the four edges **Y 8**mm. This will add depth to the recess.

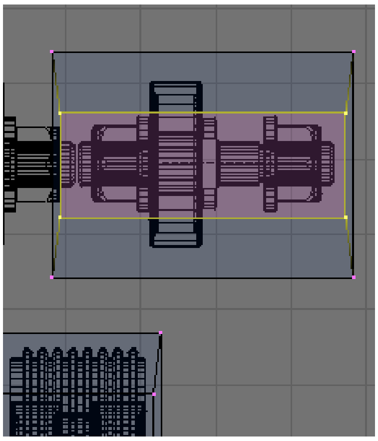
In side view **G**rab the top back vertices and move them, **Z -8** mm to give a 45 degree angle. Move the bottom vertices up 8mm.

In top view move the back side vertices in 1mm to add a withdrawal taper.

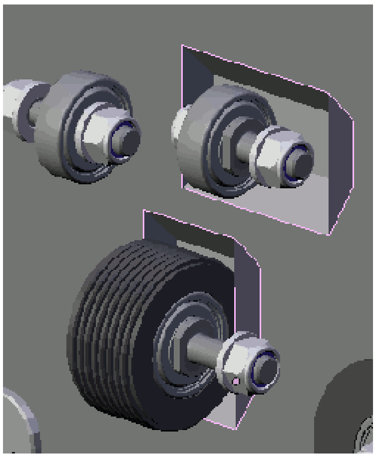
Finally add a face to form the back wall.



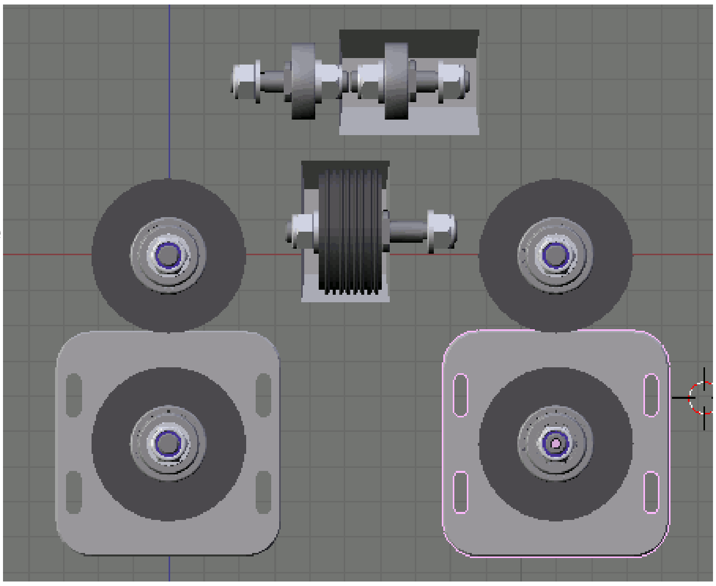
I have repeated the process for the top Right-hand bearing. This time making a little extra room for the axle and nut which also penetrate the front plane of the casting.



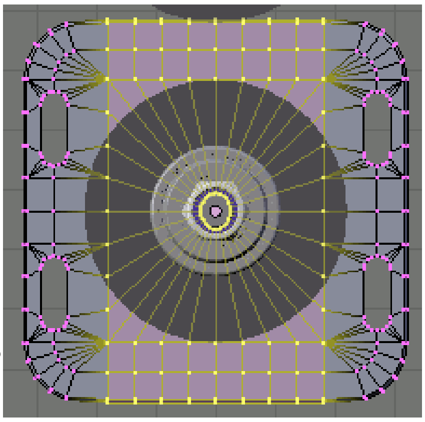
With the two recesses modelled it's easy to see where the rest of the components can be repositioned to make the casting more compact.



Theirs plenty of room to allow me to move the V-roller centres from 150mm to 110mm. It's also apparent the Adjuster blocks are larger than they need to be so I will reduce their size.

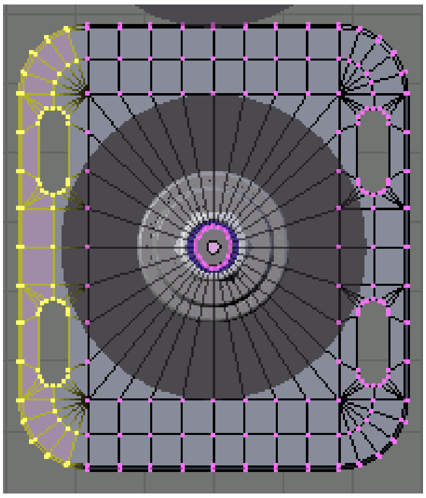


Select one of the adjuster blocks and **Tab** into edit mode. It's not possible to just scale everything to a smaller size because this will also resize the centre hole, slots and flange widths. So I need to resize it in stages.



The square centre hub is 44mm and I am going to reduce it to 36m. Box select the centre hub and flange vertices directly above and below it. **S**cale this on the **X**-axis by **1.2222** (44 / 36).

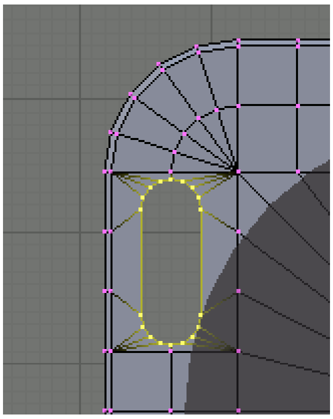
Now box select the vertices of the right hand flange and move **G** these on the **X**-axis **-4**mm (1/2 the 8mm difference).



Repeat this with the left-hand flange. Moving it 4mm on the X-axis.

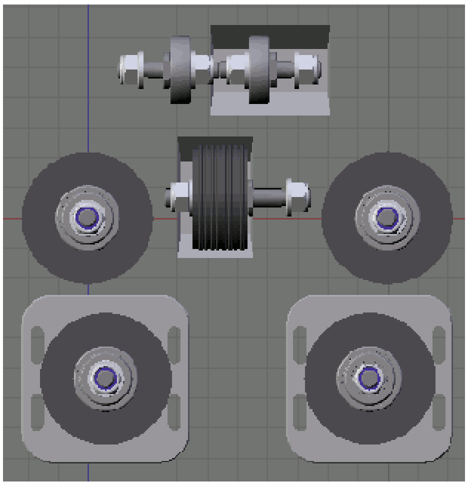
Box select the vertices of the centre boss and the flange vertices directly to the left and right of it and again scale this 1.2222 but on the Z-axis. Then grab and move the top and bottom flanges 4mm.

You should now have a square adjuster block.



In scaling the adjuster on the Z-axis we have also just scaled the slotted bolt holes. These need to be returned to their original size. We can do this by scaling the vertices of the slots by the inverse of the original scale (1 / 1.2222 = 0.81818).

Select the vertices of the first slot and **S**cale it **Z 0.81818** Repeat this on the other three slots.



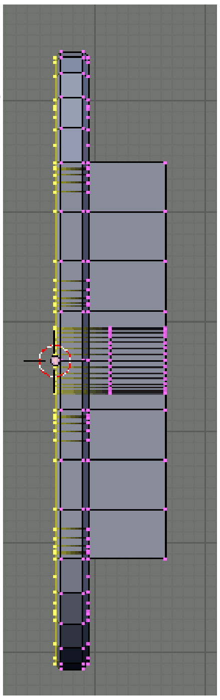
Finally scale the centre hole on the X and Z-axis by the same amount to return the hole to the correct diameter. (**S**cale **Shift-Y 0.81818**)

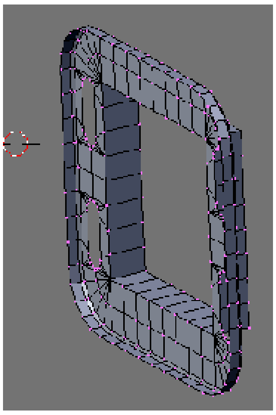
With the adjuster blocks reduced in size I have been able to further reduce the V-roller centres, which are now 100mm apart. I have also moved the bottom V-rollers in 6mm so the edge of the adjuster blocks are level with the outside of the top V-roller's.

To form the pockets in the casting where the adjuster blocks sit we can copy both adjuster blocks **Shift-D** then press **Esc**ape to leave them in position. We can then cut and adapt the copied adjuster blocks mesh to form the adjuster locations in the casting.

With the copied blocks still selected go into local view **NumPad /**. In side view select the front face of the adjusters. Snap the cursor to the selection so it's on the same plane as the front face, then delete the vertices.

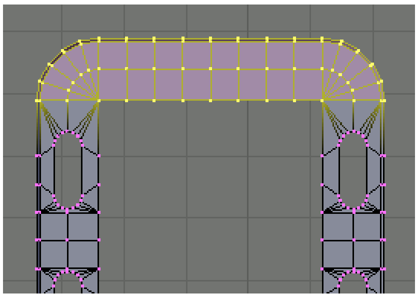
Because of the chamfer the front loop of vertices is no longer aligned on to the front face of the casting. Loop select the front edge and in cursor select mode **S**cale the vertices on the **Y** axis to **0**. This will bring the edge back into alignment.



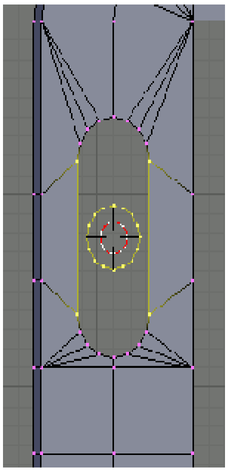


Select and delete the vertices of the central hole, to leave us with a recess the same shape as the adjuster.

If it were left like this there wouldn't be any room for the adjuster to slide on the Z-axis. So we need to mover the top and bottom flange to allow the adjuster to move.



Select the vertices of the top flange and **G**rab them moving them on the **Z**-axis **4.5**mm. Move the bottom flange -4.5mm. This will give us the room for the adjuster block to move up and down.

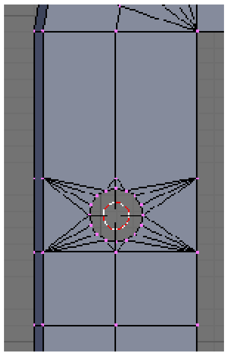


The adjusters will be secured with a 4mm bolt, so the casting needs a 4mm-tapped hole centrally to the slot.

It's not practical to model the thread so it will simply be represented by a hole at the tapping drill size, which is 3.3mm.

Select the four vertices from the straight edges of the slot and snap the cursor to their centre. Add a circle with 16 vertices and a radius of 1.65mm.

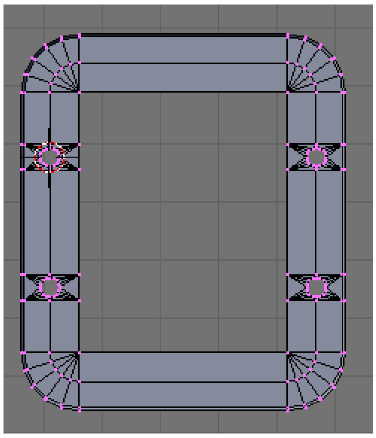
Delete the vertices of the slot then rebuild the faces around the hole.



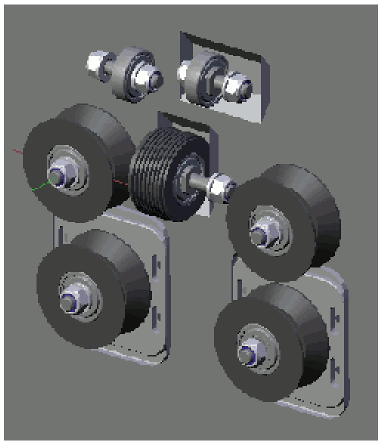
Using Blenders snap tools, copy and paste the hole and surrounding faces to the other locations.

At this stage it will also be good to delete unnecessary vertices and rebuild the faces as larger quads.

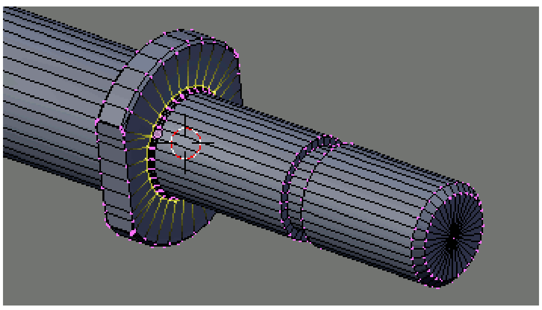
Blenders skin Face/Edge Loop feature will be useful for this.



Once one adjuster recess is complete, copy it and move it 88mm on the X-axis so it sits behind the other adjuster.

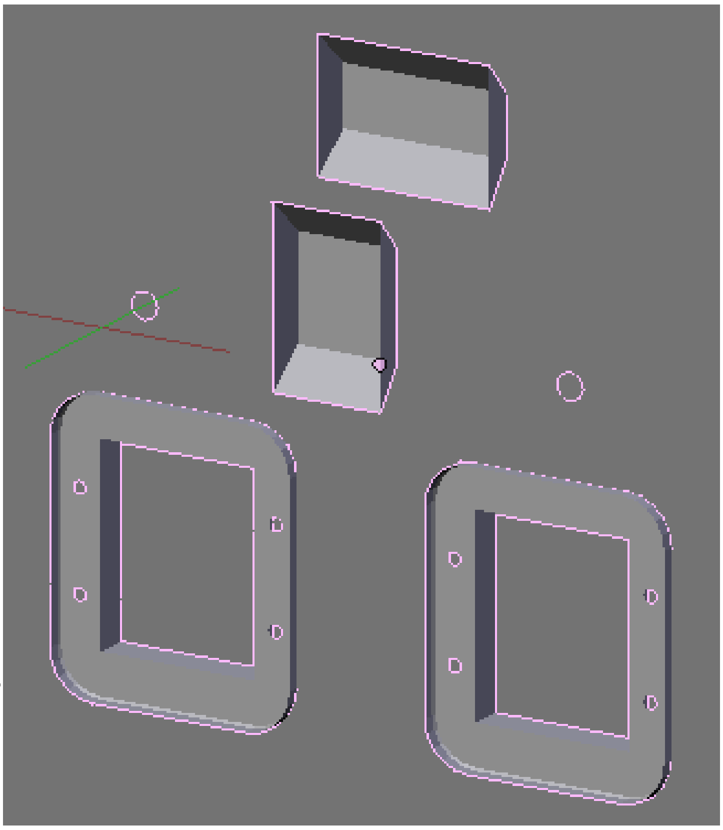


To position the fixed axle holes, **RMB** select a fixed axle and go into Local View **NumPad /**. Select **Shift-Alt-RMB** the loop of vertices at the back of the fillet and snap the cursor to the centre of them, **Shift-S** Cursor>Selection. This gives us the location point for the adjuster. Go into Object Mode and in front view Insert a mesh circle, **SpaceBar** Add>Mesh>Circle, in the pop-up menu set Vertices: 32 and Radius: 3. Repeat this for the other axle.

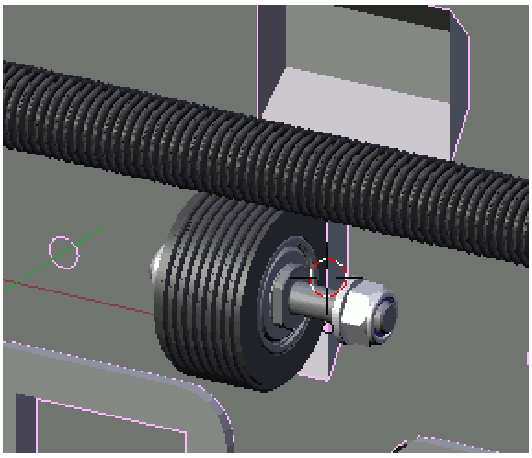


Select the axle location circles, the pockets behind the roller-nut and bearing and the adjuster recesses and combine them into one mesh, **Ctrl-J**.

These are the first features of the casting.



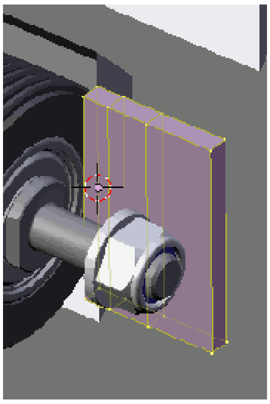
In order to locate the roller-nut and bearings, three adjuster brackets are required. I will construct these in Part-3. This will then allow me to add their mounting locations to the casting.



To finish off all the mounting locations on the casting, we need three more components, the mounting brackets for the Roller-nut and support bearings. Because the design of the brackets relies on the position of the casting face from the axle centres and also any pockets in the casting, it has not been possible to design the brackets until now.

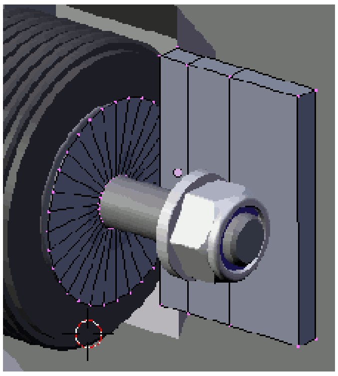
Hide all the components other than the Roller-nut assembly, casting and lead screw. It will be easier to see the available space for the bracket without the other components.

Tab into Edit Mode for the casting and snap the cursor to the front face. I have selected the two vertices of the recess, so the cursor is on the edge of the recess and aligned with the mounting face of the axle.



Back in Object Mode, add a Plane. Scale the left-hand side vertices to the cursor, its height to 30mm and width to 4mm. Extrude the right hand vertices on the X-axis 6mm then again on the X-axis 10mm, the 6mm section will be used to form a locating key, the 10mm section will become the bolt flange.

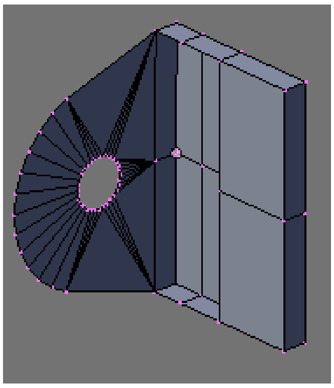
Extrude the three faces to give a thickness of 3mm.



Tab into Edit Mode for the axle and snap the cursor to the vertices on the flange fillet as detailed in Part 1. Tab back into the adjuster Bracket.

In side view add a circle with 32 vertices and a 3mm radius.

Extrude these vertices then press **Esc**ape to leave them in position. cale the extruded vertices by a factor of 4 to give a 24mm flange.



Delete some of the vertices from the outer circle and add edges back to the mounting flange. With careful choice you can get a tangential alignment.

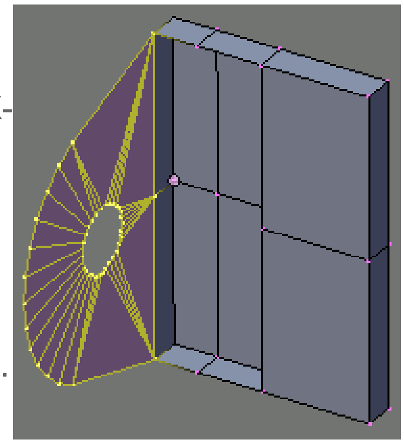
Midpoint cut a row of vertices on the mounting flange and delete the vertex that would become inside the bracket. This will remove four faces from the mounting.

Rebuild new faces around the hole.

Select the vertices indicated and Extrude them on the X-axis 4mm then again 6mm.

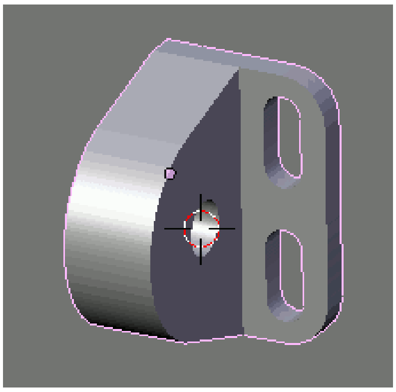
In wire view delete the vertex that has been created internal to the bracket. Select all and remove doubles.

You will also need to rebuild the faces of the original face, as these will be removed by the extrusion process.



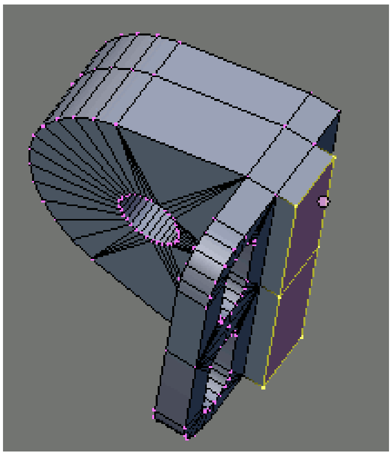
As detailed in Part-1 for the V-roller adjuster brackets add two elongated holes to the flange and also a fillet to the outer corners.

Finally the bracket needs to be constrained to a movement perpendicular to the lead screw.



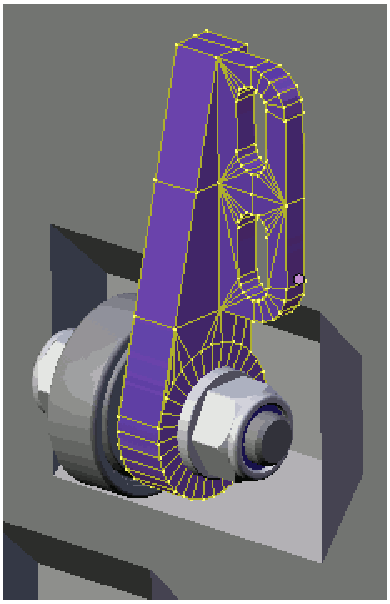
To achieve this I have purposefully created vertices that will allow the incorporation of a key, which will be located in a slot machined into the face of the casting.

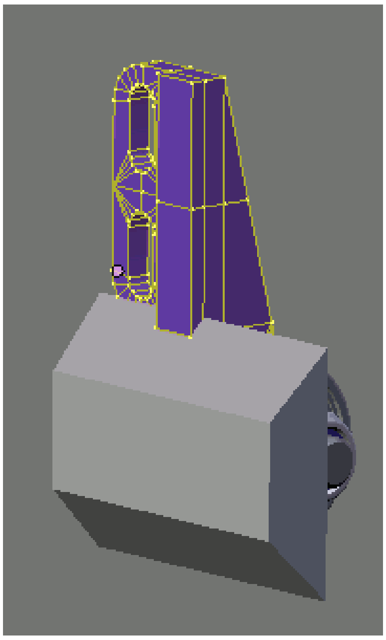
Select the two faces indicated and extrude them 2mm.



The support bearing adjusters are modelled in a similar way to the Roller-nut adjuster bracket. I have slimmed down the bracket to 6mm and moved the mounting flange above the bearing.

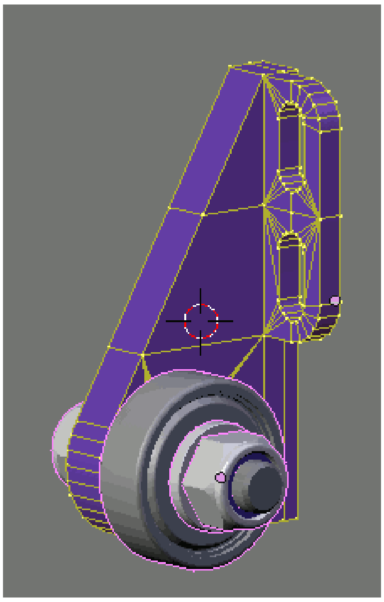
The right hand adjuster will be set back into the pocket provided in the casting.



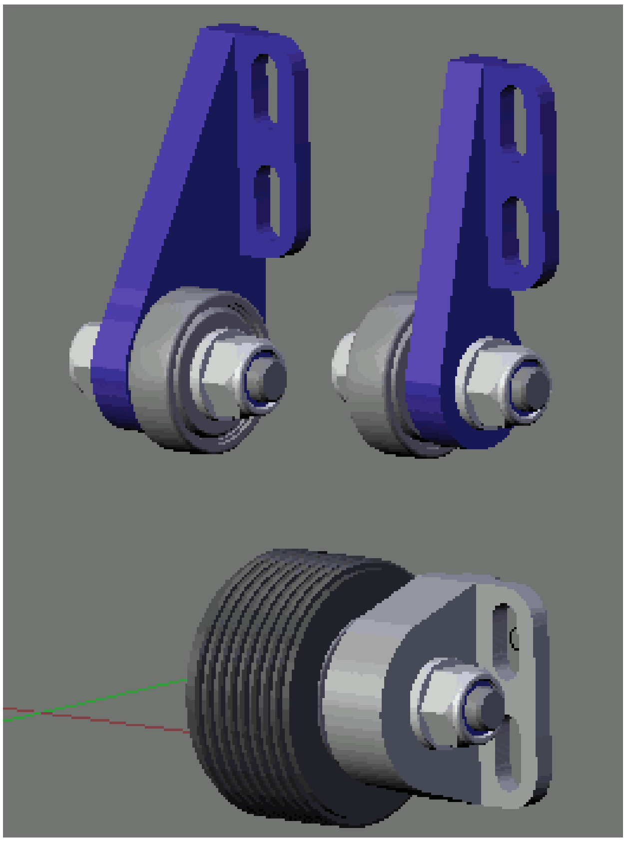


The view from the back shows the 6mm key, which penetrates the face of the casting.

Some work will be required to provide the mating slot in the casting and the bolt holes.

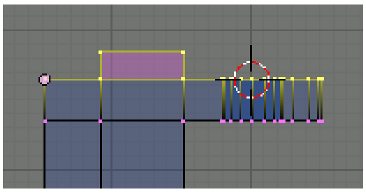


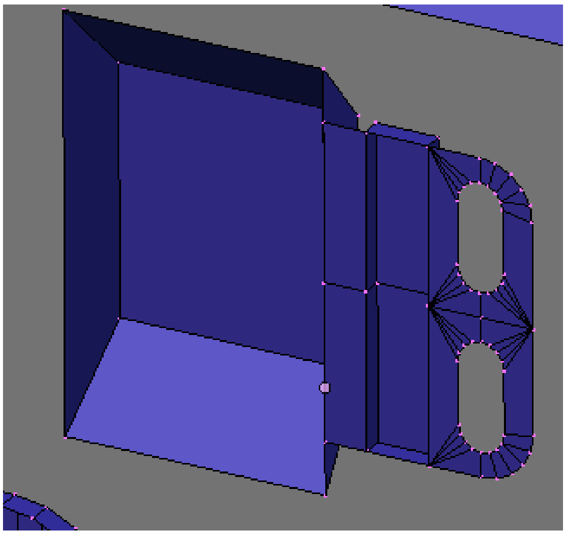
The left-hand adjuster stands out further from the casting to allow support forward of the lead screw centreline.



Transferring Geometry to the Casting

Select an adjuster and **Tab** into Edit Mode. In top view **NumPad 7** select the vertices on the back face of the adjuster.





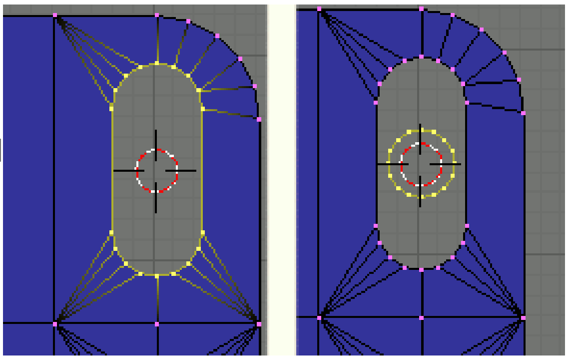
Copy the vertices **Shift-D** then **Esc**ape to leave the copy in place. Separate the copy from the adjuster mesh **P**.

Tab into Object Mode and select the copied adjuster face, then **Shift-RMB** select the casting. Join the copied face to the casting **Ctrl-J**.

Repeat this for all three adjuster brackets.

Some work is now needed to modify the copied geometry to suit the casting.

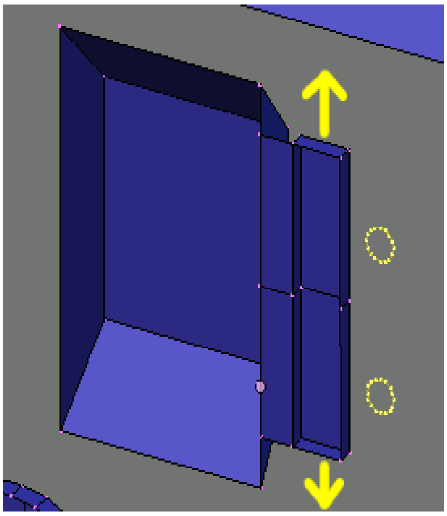
As with the V-roller adjuster, the lead screw adjusters will be secured with 4mm bolts, so the casting needs 4mm-tapped holes centrally to the slot.



Again these will be represented by a hole at the tapping drill size, which is 3.3mm.

Alt-RMB Select the vertices from the slot and snap the cursor to their centre. Add a circle with 16 vertices and a radius of 1.65mm. Repeat this for all slots.

Delete the unnecessary vertices, leaving the key way slot and tapped hole circles.

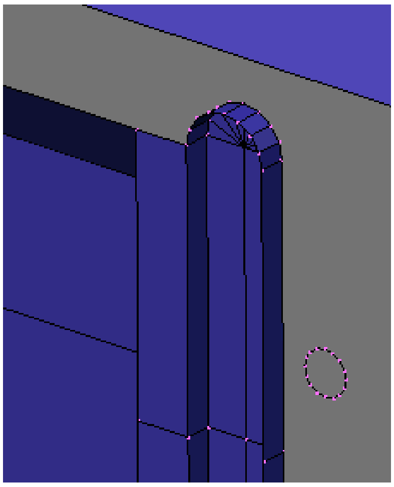


In order for the adjuster to move in the slot the slot length needs to be increased by at least the amount of movement available on the elongated bolt holes.

Grab the top vertices of the slot and move them on the Z-axis 5mm.

I have also cut the slot lengthways with a mid point cut. This has enabled me to spin a radius at the top of the slot, which on the casting will be cut using a 6mm slot drill, giving the radius on the ends.

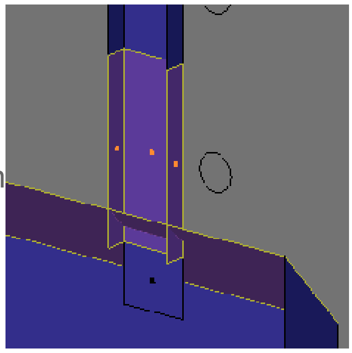
A mid point cut has also been made horizontally across the recess to align vertices with the centre vertices of the key slot.



The slot on the top right adjuster poses a different problem, as it has to penetrate the face of the bearing recess.

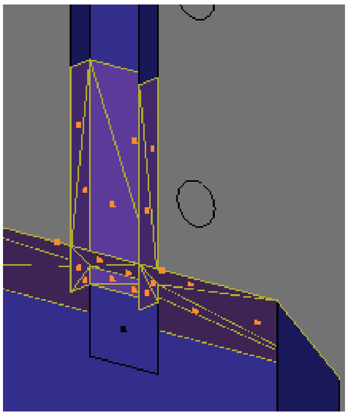
To add vertices and edges for this penetration use the Geom tool. Select the intersecting faces and in a script window choose Scripts>Mesh>Geom Tool

Select Intersect: Face(s) (Cut)



The Geom Tool will cut a new series of edges around the intersection. It will also triangulate all the selected faces.

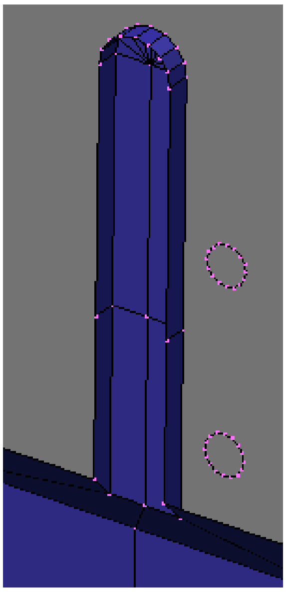
Delete all the unnecessary faces and convert the remainder to quads, **Alt-J**.

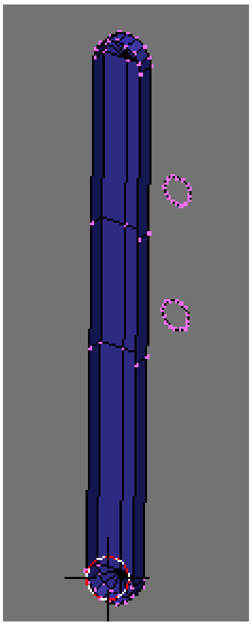


Extend the top of the slot 5mm to allow the adjuster bracket room to slide.

Cut a vertical row of vertices down the slot and bearing recess, using the knife with a mid point cut.

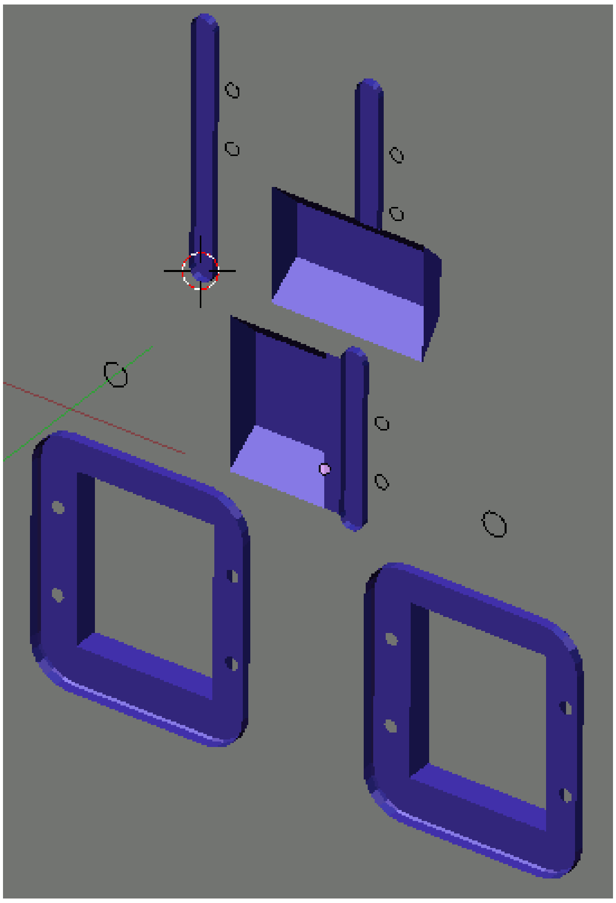
Spin the top radius.





The left-hand adjuster slot just needs to be extended 5mm top and bottom.

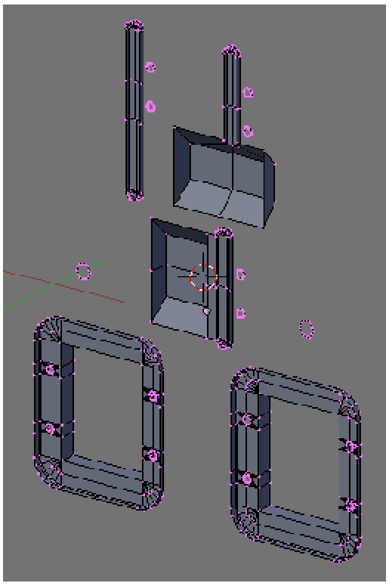
A vertical mid point cut will allow the ends to have a radius spun to match the slot width.



All the mating geometry needed to complete the casting has been accurately extracted from the component assembly.

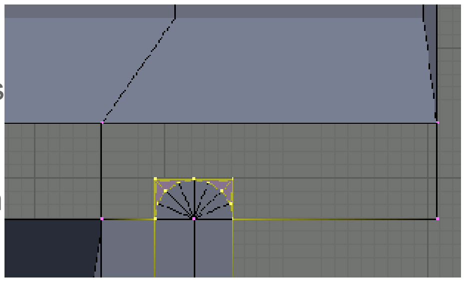
In the next part I will complete the casting by building faces between all the extracted geometry elements.

With the location of the bolt holes, Key way slots, adjuster housings and recesses now positioned all that remains is to build the face of the casting between the edges already modelled.

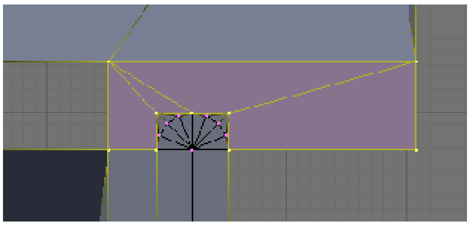


However, to keep an organised mesh, it is necessary to build up a framework of edges, before auto filling individual areas.

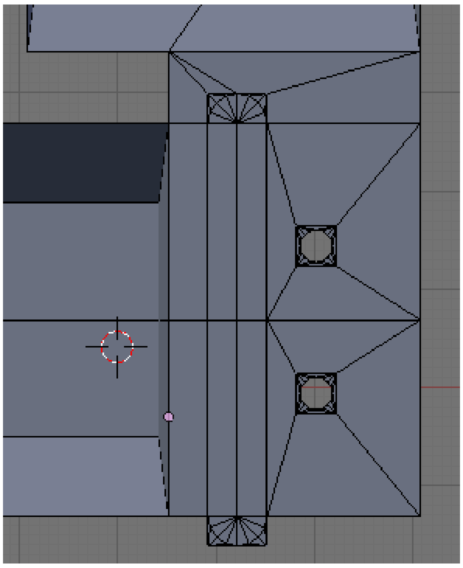
Most of the parts we have created for the casting are not in horizontal alignment so a little bit of work is needed to provide vertices in the best location for the auto fill.



Section off areas of the casting by extruding edges horizontally or vertically. Snap the cursor to existing vertices and in cursor select, Scale the other required vertices along their axis to 0 to align them.

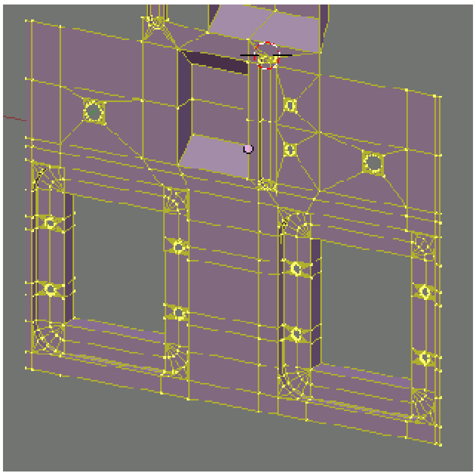


Use Auto Fill **Shift-F** in aligned regions. Beautify the fill **Alt-F** and convert trie's to quads **Alt-J**.



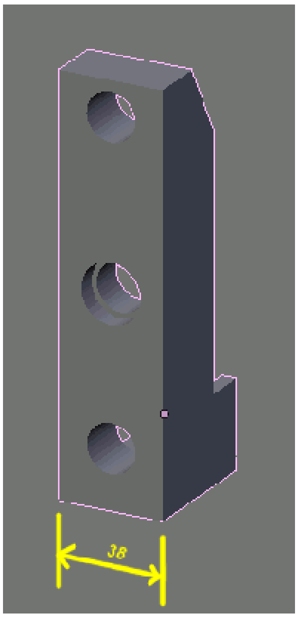
By constraining regions vertically and horizontally you can construct an organised mesh. The advantage of doing this are that if alterations are required to the model selection of aligned rectangles will be much easier than selecting areas of a mesh made up of disorganised triangles.

Before completing the face of the casting there is one other element that needs to be fixed to the X-axis slide. That is the support for the Y-axis.

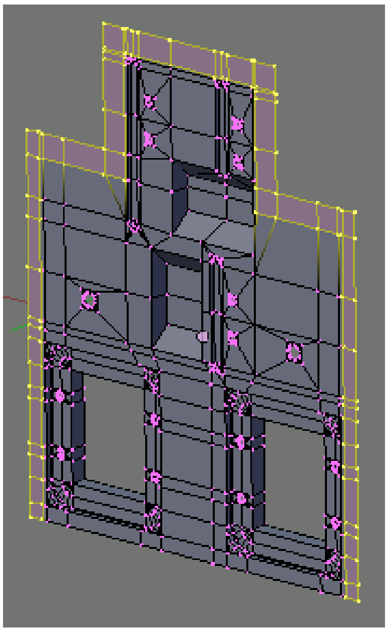


As I have already roughed out my design I know the locating area for this needs to be 38mm wide.

The top section of the X-axis needs an area that the Y-axis can be bolted on to. To save having a left and right-hand X-axis casting I will incorporate the mounting on both sides of the casting.

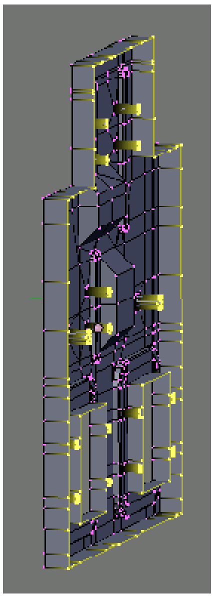


As part of the casting's inner face I have incorporated a loop of faces around the outer edge, these will become a flange to help stiffen the casting and also give the mounting location for the Y-axis support bracket.

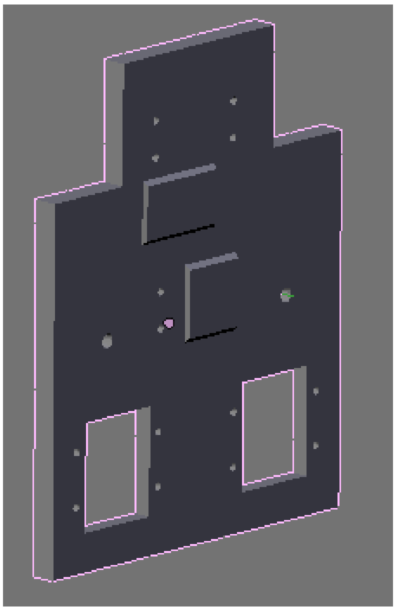


Extrude the holes and the outer edge back to give the casting thickness.

Once all the elements of the back face are on the correct alignment build faces between them in a similar manner to the front face.

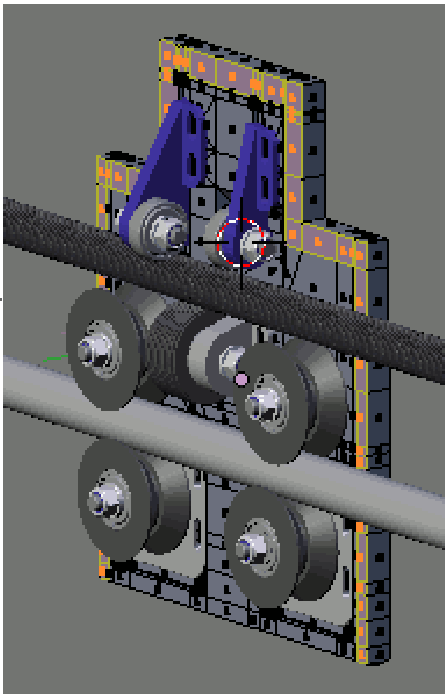


Because I haven't done any investment casting before I am not sure how thin the mould can be before it won't fill properly. Because of this I have increased the thickness behind the pockets to 4mm.



Select the loop of faces from around the outer edge of the inner face. These will be extruded to provide a mounting point for the Y-axis and also offer some protection to the components of the X-axis.

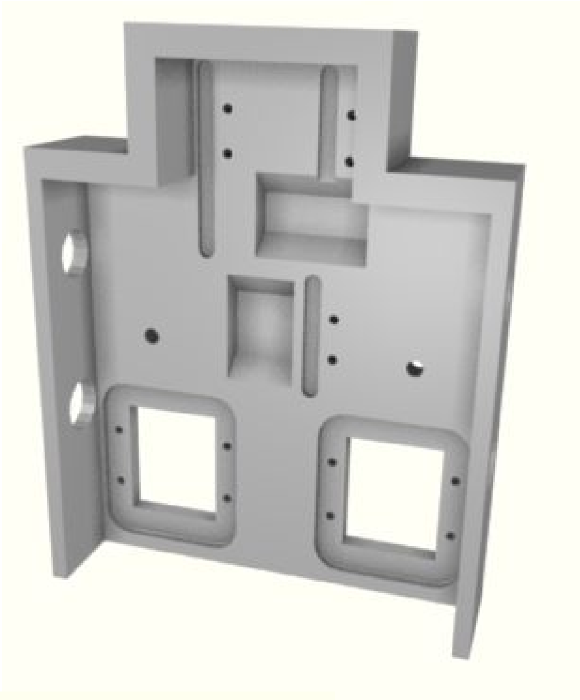
Extrude the faxes 30mm to clear the V-rollers then cut clearance holes for the lead screw and guide shaft.

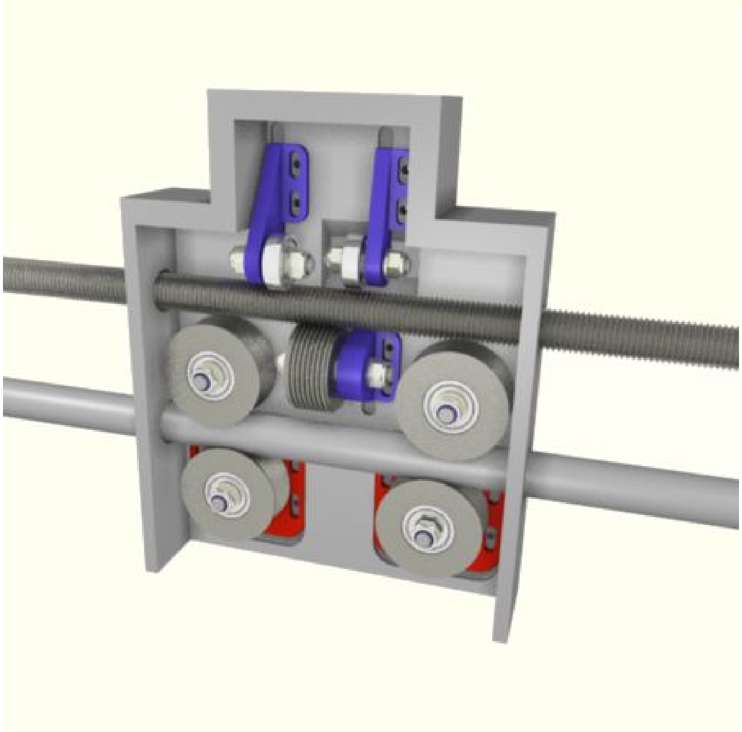


This completes the casting for the X-axis of my CNC router. All that remains is for me to make a wax pattern, which will be fabricated, from templates printed at a scale of 1 to 1 from the Blender model.

This model is constructed at finished size. Extra metal will be required on the areas that are to be machined.

I will detail the progress of the casting in the Engineering section of my web site.





This is the final part of the Engineers Guide to Blender. Hopefully you have been able to understand the processes introduced in the Guide and will be able to build on your experience by producing designs of your own.

If you were new to Blender when you started the guide and have worked through to this final page, you should now be comfortable with Blenders way of modelling. Theirs still a lot to learn and many more tools and techniques available to improve your modelling skill. How you progress from here is up to you, but the Internet community offers numerous tutorials and guidance, so you have no excuses for not progressing and becoming a Blender pro.